A Summary of Current Program, 7/1/63

and Preliminary Report of Progress

for 7/1/62 to 6/30/63

ENTOMOLOGY RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Section A

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between July 1, 1962 and June 30, 1963. Current agricultural research findings are also published in the monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE
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TABLE OF CONTENTS

INTRODUCTION

Entomology research is concerned with both destructive and beneficial insects in relation to the growing of fruits, vegetables, forage, grain, cotton, tobacco, sugarcane, sugarbeets, and ornamental crops; the management of bees in relation to pollination and honey production; and the production of all classes of livestock and poultry. In addition, it includes investigations on insects affecting man, households, and industrial establishments; the identification and classification of insects; the biological control of weeds; and on chemicals including insecticide residues on all raw agricultural commodities derived from crops and livestock.

Insects (including ticks and mites) constitute the largest class of animals. Approximately 85,000 kinds occur in the United States, of which 10,000 are regarded to be of economic significance. Insects are both destructive and useful. They are man's greatest competitor for food and fiber, and at the same time they are vital to man's existence. Without honey bees and other insect pollinators, many important crops could not be grown, and without the insect parasites and predators, which help to maintain a reasonable balance between harmful and beneficial species, destructive insects would increase to such numbers that it would almost be impossible to control many of them even with our best control measures.

All crops in every stage of growth are subject to attack by insects. Seeds placed in the ground may be destroyed before or during sprouting. Growing plants have their roots, stems, leaves, or fruit damaged by many kinds of chewing and sucking insects. Livestock are infested by numerous insects, ticks, and mites. Insects are important in that they cause annoyance and losses due to direct feeding and also because they are responsible for the spread of many of the most serious diseases affecting plants, animals, and man. Thus, it is understandable why insects exact a toll of the Nation's resources estimated at 4 billion dollars annually.

Outstanding progress has been made in the development of control methods for most of the major insect pests, by developing chemical, cultural, biological and genetic control procedures. Of these various procedures, chemical control methods are now employed to meet about 90 percent of our insect problems. However, the use of insecticides has led to many problems that are of growing concern to the public, such as residues in foods, and adverse effects to fish and wildlife, beneficial insects, and other organisms in the treated environment. Because of such problems major shifts in emphasis have been made in the entomology research program to strengthen research on biological control methods, the development of plant varieties resistant to insect attack, attractants and baits to provide specific methods of control for certain insects, and the exploration of other new approaches such as the use of sterile insects for their own destruction. All of these methods offer excellent possibilities for improving insect control and eradication procedures.

The Entomology Research Division has work located at 61 field locations in the United States, 4 locations in foreign countries, one in Puerto Rico, and one in Guam. Of the total professional staff of 401, 101 are located at the Agricultural Research Center, Beltsville, Md., or at Washington, D. C. The Division and the Branch leadership staffs responsible for the administration of research programs throughout the country and abroad are headquartered at Beltsville, Md. Two Pioneering Laboratories, one on Insect Pathology and the other on Insect Physiology, both devoted to basic research, are also located at Beltsville. In addition, basic research is conducted by entomologists and chemists at Beltsville, in cooperation with scientists of other disciplines. Insect identification research is conducted in Washington in close collaboration with the Smithsonian Institution.

The personnel at field locations cooperate closely with State Experiment Station and university scientists. There is also close cooperation with trade associations, industrial establishments, health agencies, and growers. Most of the applied research is conducted at the field locations and such research will continue; however, more and more attention is being given to basic investigations pointing to better long-range solutions to insect problems of national significance.

Cooperation is also maintained with other research divisions in the Agricultural Research Service and with divisions of the Service concerned with plant and animal pest-control and plant and animal quarantine programs. There is also cooperation with other research and regulatory divisions in the Department of Agriculture and with other agencies including the Department of Defense, Department of Health, Education, and Welfare, Department of Interior, World Health Organization, and Agency for International Development.

A broad analysis of the Division's research by different approaches to insect control shows that about 30 percent of the current effort is on the conventional chemical approach to insect control; 16 percent on biological control (parasites, predators, and pathogens); 6 percent on plant resistance to insects; 17 percent on the sterility and other new approaches to insect control such as natural attractants; and 31 percent on other entomology research including basic biology, physiology, taxonomy, apiculture, and insect vectors of diseases. Substantial changes in the research effort have been made in the last 5 years, largely by shifts within available funds, to place more emphasis on nonchemical or on special chemical approaches to insect control.

The following examples of outstanding achievements in research by scientists in the Entomology Research Division illustrate the value of entomological research in the improvement of the Nation's agricultural economy and general welfare of the people:

Plant varieties resistant to insect attack. Although only limited effort has been devoted to the development of plant varieties resistant to insect attack, excellent progress has been made in dealing with several important insect problems by this desirable control method. This progress has been the result of cooperative research by Federal and State entomologists and plant breeders. Seventeen varieties of wheat that possess resistance to the hessian fly, a long-time serious pest of wheat, have been developed and released to the growers by State Experiment Stations in cooperation with the U. S. Department of Agriculture. Nine of the resistant varieties were released in 1960-62. Today hessian fly-resistant wheats are being grown on more than 4,500,000 acres of winter wheat. As a result this formerly major pest has been relegated to the status of a minor pest of wheat. Rapid progress has been made in the development of varieties of alfalfa highly resistant to the spotted alfalfa aphid, an important pest accidentally introduced into the United States in 1954. After only a few years of research, four varieties--Lahontan, Moapa, Zia, and Cody--each adapted to particular areas, are now being grown in the Western States. In addition Sonora, a new nondormant spotted alfalfa aphid resistant variety developed in the cooperative alfalfa improvement program in Arizona, California and Nevada, has recently been released in those States. A variety of barley named Will, bred specifically for greenbug resistance, has been approved for release by the Oklahoma Experiment Station. It is estimated that this variety will be worth more than $5 million annually to farmers in the area infested by the greenbug, an aphid that is especially destructive to barley. Two varieties of wheat, Rego and Sawtana, that possess resistance to the wheat stem sawfly, have been released by the Montana Experiment Station. Another resistant variety, Rescue, has been grown for a number of years in sawfly-infested areas.

Attractants, baits, and sterilants for fruit fly control. Fruit flies constitute the most important insect threats to our tropical fruit industries. Research in Hawaii and Mexico has led to major advances in methods for controlling or eradicating these pests. Several outstanding lures, including methyl eugenol, trimedlure and cue-lure, have been developed which attract males of the oriental, Mediterranean and melon flies. They are of vital importance in early detection of infestations and can be useful in control. In addition, work on attractants for baits has led to the protein hydrolysate-malathion bait spray which was used for eradicating the Mediterranean fruit fly in Florida in 1957 and again in 1962. The eradication of the oriental fruit fly on the island of Rota in the South Pacific was accomplished in 1963 by luring the male flies to a specific attractant, methyl eugenol, containing a small amount of the insecticide naled that killed them. This was the first demonstration of the principle of insect eradication by male annihilation. In the same year the melon

fly was eradicated on Rota by reducing the wild flies to low numbers with a malathion-protein hydrolysate bait and then exposing the remaining population to mass releases of male flies sterilized by gamma radiation. This research demonstrated the practical value of the sterility method as applied to an insect population already depleted by the use of a toxic bait.

Sex attractants--a new approach to insect control. The isolation, identification and synthesis of the powerful sex attractant found in gypsy moth females represents a break-through in research on the development of highly specific methods for insect detection and opens the way for a new desirable approach to insect control. The attractant produced by virgin female American cockroaches has been isolated and identified. Recent research has shown that virgin female adults of several major pests, including the European corn borer, house fly, cabbage looper, cotton leafworm, pink bollworm, tobacco hornworm, tobacco budworm, cockroaches, peach tree borer, lesser peach tree borer, and banded cucumber beetle, contain specific sex attractants. Research on methods of isolation and on the chemical composition of the natural attractant substances that is now underway should lead to their future synthesis.

Insect control in relation to human health. Department entomologists and chemists, since World War II, have carried out research for the Department of Defense on pests and insect vectors of diseases of concern to our military personnel. Outstanding contributions have been made in the development of ways to control insect vectors of major diseases which have not only been important to our national defense but of great benefit to human welfare. The residual insecticide method of malaria control used by health agencies throughout the world is based on original research of ARS scientists. All of the insecticides used for controlling lice that transmit the serious typhus disease were also developed by them, as well as new insect and mite repellents that are used by both military personnel and civilians as a means of personal protection from pests and disease carriers.

Sterility method of insect control. A new concept in controlling insects and other pests has been developed which may contribute to the solution of some major insect problems. The method involves the release of sterile insects for their own destruction. The mass production and release of screw-worm flies made sterile by gamma radiation resulted in the elimination of this important livestock pest from the Southeast. A similar and more complex program based on the same principle which is now underway in the Southwest has already greatly reduced screw-worm infestation in the area. The utilization of sterile insects was responsible for the eradication of the melon fly from the South Pacific island of Rota, and the method is being intensively investigated as an aid to the control or

eradication of other major pests, including the boll weevil, pink bollworm, sugarcane borer, codling moth, tobacco hornworm, and other pests. An important advance in research on the sterility method has been the development of several chemicals which produce sterility in insects with less damage to the insects than that caused by radiation. The availability of such chemicals also offers the possibility of discovering ways to induce sterility in the natural insect population, thus obviating the necessity of rearing and releasing insects sterilized by radiation to achieve control.

Insect pathogens. Encouraging results have been obtained in basic and applied research underway on insect diseases-bacteria, fungi, protozoa, and viruses -- aimed at the ultimate production and use of such organisms to control insect pests. Disease organisms generally are highly specific and seemingly pose no danger to man or animals. The milky disease of the Japanese beetle, developed and put to practical use years ago, is still an important aid in the control of this insect. Polyhedral viruses of the cabbage looper and corn earworm have shown promise as effective and specific controls for these two important agricultural pests. Certain strains of Bacillus thuringiensis, a bacterium already being produced commercially and used against several species of insects, produce a number of different toxins which may be isolated and possibly prove of exceptional value as control agents.

AREA NO. 1. VEGETABLE INSECTS

Problem. Insects and mites are important limiting factors in the production of high-quality vegetables. They reduce the yield, lower the quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. The use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating milk and meat by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides. The drift of certain insecticides into other fields or areas can also cause problems. Another difficulty is that a number of vegetable insects have developed resistance to certain insecticides. For many vegetable insects there is an increasing need for safe, effective, and economical methods of control that will not leave harmful residues on the marketable produce or adversely affect the flavor or quality. Research is needed on methods for better utilization of predators, parasites, and insect diseases of vegetable insects; the development of varieties of vegetables resistant to insect attack; the development and utilization of more effective traps and lures; an exploration of new approaches to control including radiation, chemosterilants, and antimetabolites; and an evaluation of insecticide application equipment. Such developments would help decrease the necessity for employing hazardous chemicals. Better methods are required to forecast possible insect damage before it occurs on vegetables, and to determine when it will be necessary and profitable for growers to apply control measures.

USDA PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz.; Riverside, Calif.; Tifton, Ga.; Twin Falls, Idaho; West Lafayette, Ind.; Beltsville, Md.; State College, Miss.; Forest Grove, Oreg.; Charleston, S.C.; Logan, Utah; Baton Rouge, La.; and Yakima, Wash., in cooperation with the respective State Experiment Stations and industry. Much of the work is in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. The work in Idaho is also cooperative with the Idaho Bean Commission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. The work in Oregon is conducted jointly with the Agricultural Engineering Research Division. The work in Louisiana is under contract by the Louisiana State Experiment Station.

The major objective of this work is to develop more effective and economical and less objectionable methods of controlling insect pests of vegetables in the field to reduce losses from these pests without leaving undesirable insecticide residues on or in the marketed product or in the soil, and

without affecting the flavor or quality of the product, and without adversely affecting beneficial insects. Increased emphasis has been given to new approaches to insect control. It is necessary to learn more about the biology and habits of the pest insects with the object of developing methods of controlling them without using insecticides. A widespread search is in progress for sex lures that can be utilized in insect detection and control, requiring a much better knowledge of mating habits of the various insect species. Also underway are studies of male sterilization techniques for such insects as the cabbage looper, drosophila, the banded cucumber beetle, and the Mexican bean beetle by means of gamma radiation and chemical sterilant techniques that may permit insect control on an area basis.

The Federal scientific effort devoted to research in this area totals 26.8 professional man-years. Of this number 3.0 is devoted to basic biology, physiology, and nutrition; 5.1 to insecticidal and cultural control; 5.4 to insecticide residue determinations; 3.6 to biological control; 2.8 to insect sterility, attractants and other new approaches to control; 2.2 to evaluation of equipment for insect detection and control; 1.7 to varietal evaluation for insect resistance; 1.7 to insect vectors of diseases; and 1.3 to program leadership. The Walla Walla, Wash., station was closed in October 1962 and the funds and personnel transferred to Yakima, Wash., where increased emphasis will be given to the study of pea aphid control by sustained releases of reared parasites.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Cabbage Looper and Other Lepidopterous Pests of Vegetables. At Mesa, Ariz., studies were initiated in May 1963 to determine the seasonal occurrence and abundance of adults of the cabbage looper, alfalfa looper, beet armyworm, yellow-striped armyworm and corn earworm. Seven blacklight traps placed in various locations in the east end of the Salt River Valley showed that flight peaks occurred during mid-May for all of these moths. They also showed the cabbage looper and beet armyworm moths to be the most numerous of the five species under observation. Lettuce, cole crops, and sugarbeets cannot be grown in this area without controlling these insects which are also important pests of cotton.

At Charleston, S.C., a semi-artificial medium composed of dried collard leaf, ascorbic acid, water, and microbe inhibitors was used successfully to rear cabbage loopers to the pupal stage. However, newly hatched loopers developed very slowly on the medium, requiring 19 days to reach the pupal stage. An entirely artificial diet was less promising in initial trials.

2. Drosophila. In studies during 1962 at Beltsville, Md., on possible control of drosophila in tomato fields by the sterile-male technique, 3.2 million drosophila flies were reared at a cost of six cents per thousand for the rearing medium and other materials. An apparatus was designed and

used during the 1962 season to separate the males from the females. The males, weighing about half as much as the females, rose higher in a column of air in the apparatus and were removed from the upper part of the column through a side tube. The final separation consisted of about 92% males and 8% females; the latter were mostly undersized individuals that rose with the males in the air column and were not separated on the differential weight basis.

3. Leaf Miners. Commercial greenhouse tomatoes in Ohio are being damaged by Liriomyza leaf miners. At Beltsville, Md., a species of leaf miner from local chrysanthemums was established on greenhouse tomatoes and also in experimental field plots of tomatoes where it caused damage until frost. Infestations maintained during the active season of 1962 on caged field tomatoes and pupae from the greenhouse placed in soil under debris in the same cages failed to survive the winter of 1962-3. Apparently this species cannot survive the cold winters of northern areas. Continued infestations depend upon survival in greenhouses or reinfestations from warmer areas. Evidence has been obtained that recent infestations on greenhouse chrysanthemums in Ohio originated from cuttings of chrysanthemum grown in California and Florida.

Studies at Beltsville, Md., and Charleston, S.C., indicated that the same leaf miner that damages greenhouse crops is responsible for damage to field tomatoes in South Carolina. In 1963 this leaf miner again was present in commercial plantings in coastal South Carolina. When other factors were comparable, fields set with Florida plants had higher infestations throughout the season than those set with homegrown plants. Four and a partial fifth generation of the insect apparently developed in fields set with imported plants. Insect parasites played an important role in reducing leaf miner populations, but many of these natural enemies were killed by insecticides applied for control of leaf miners and other insects.

4. Southern Potato Wireworm. Approximately 5 to 15% of the recently-transplanted tomato plants in 3 commercial plantings in coastal South Carolina were killed as a result of the tunneling of the larvae of this insect into stalks of the plants. This is the first known report of such injury to tomato by this insect.

In South Carolina close examination of the southern potato wireworm showed that in the pupal stage the females have two protruding buds on the ventral side of the last abdominal segment and the males three such buds. The accuracy of sexing pupae by use of these characters was determined by study of the emerging adults. Accurate sex identifications of the pupae are needed in current studies of mating habits and effects of chemosterilants on the insect. In the past, only the sexes of adults could be distinguished and then by undesirable methods. Pressing out genitalia injures the adults. Administering carbon dioxide will cause the genitalia to be protruded but no fertile eggs have been obtained from females so treated.

5. Beet Leafhopper. The beet leafhopper population in desert and range breeding areas of southern Idaho in the spring and early summer of 1963 was one of the lowest on record. The overwintered adult population ranged from low to moderate in various areas, and unusually rainy weather during the period when the spring brood was hatching apparently decimated the nymphs of this generation.

6. Pea Aphid. The results of a 15-year study at Walla Walla, Wash., on the ecology of the pea aphid in relation to its role in the spread of a complex of mosaic diseases of peas were prepared for publication in a USDA technical bulletin, now in press. These studies yielded basic information on the seasonal biology and movements and natural enemies of this aphid that are proving valuable in the development of control measures.

7. Banded Cucumber Beetle. Limited information concerning the length of life stages, the relative value of several materials as larval food, and other phases of biology of the insect, was obtained in South Carolina. Only 5% of the males and 1% of the females under observation in cages survived a minimum outdoor temperature of 8° F. in December 1962. Larvae died when subjected to 0° F. but survived being submerged in water at room temperature for several days. A nematode that apparently is an important natural enemy of the larvae was identified as a new species in the genus Ampimeris.

8. Sweetpotato Insects. The following insects were found in one or more of 14 sweetpotato plantings in eastern South Carolina in 1962: Banded cucumber beetle, southern potato wireworm, sweetpotato flea beetle, elongate flea beetle, tortoise beetles, spotted cucumber beetle, and the tobacco flea beetle (only in plantings near tobacco fields). Most of the injury to the roots apparently was caused by the southern potato wireworm. The appearance of injury to the roots by larvae of certain of these insects in cage studies at Charleston, S.C., was as follows: Southern potato wireworm injury consisted of fairly small irregular-shaped holes seldom more than 1/2 inch deep. Injury by the banded cucumber beetle, the spotted cucumber beetle, the elongate flea beetle, and the pale-striped flea beetle, was similar to that caused by the wireworm and consisted of small round holes through the skin and enlarged cavities just under the skin. The flea beetles tunneled into the roots much more often than the cucumber beetles, which seldom tunneled. Sweetpotato flea beetle larvae tunneled just beneath the epidermis of the roots, producing winding mines. In harvested roots these mines usually appeared as shallow, winding channels in the skin. Cucumber beetle adults fed on the leaves of sweetpotatoes producing irregular holes similar to those caused by tortoise beetles. Elongate flea beetle adults fed on the upper surface of sweetpotato foliage producing characteristic winding paths. Pale-striped flea beetle adults ate small ragged holes in the leaves. Adults of the sweetpotato flea beetle ate narrow channels along the veins on the upper surface of the leaves.

Sweetpotato roots showing extensive injury of the type caused by the sweetpotato flea beetle were received from Wicomico County, Maryland, in 1962. Photographs were received of the same type of injury in Georgia. Similar feeding was noted in Louisiana and reports of such in North Carolina and Mississippi were received. Adults of what apparently is the flea beetle, Systena blanda, were taken in sweetpotato fields in Louisiana, and adults of another flea beetle, S. frontalis, in South Carolina.

9. Spider-Mite Nutrition. In Maryland studies, cross sections of bean leaf tissue showed marked differences in shape, arrangement and size of epidermal, palisade and spongy parenchyma cells associated with host plant nitrogen supply. The greatest differences and irregularities in leaf tissue appeared when plants were supplied low levels of nitrogen. Two-spotted spider mites produced more progeny concurrent with increased host plant nitrogen supply and absorption. The greatest porportional increase in mite fecundity concurred with the changes in irregularities in the leaf tissue associated with increases in total leaf nitrogen. Although little is known concerning the effect of leaf changes on mite feeding, this factor may contribute directly or indirectly to the increase in mite fecundity.

The susceptibility of resistant and non-resistant two-spotted spider mites to malathion increased when the host plants were supplied high nitrogen, 756 p.p.m. in nutrient solution rather than 252 p.p.m. When the same strains of mites were reared on host plants supplied high phosphorus, 400 p.p.m. as compared with 100 p.p.m., the resistant mites became more susceptible but the non-resistant mites became less susceptible.

Female two-spotted spider mites produced increasing numbers of eggs according to the nitrogen supply when fed on lima bean plants growing in quartz sand and supplied nutrient solutions containing nitrogen at levels varying from 28 to 784 p.p.m.

B. Insecticidal and Cultural Control

1. Corn Earworm on Sweet Corn. Of six insecticides evaluated for control of the corn earworm at Tifton, Ga., Bayer 41831 at 2 pounds per acre, Bayer 44646 at 1 pound per acre, Bayer 47940 at 2 pounds per acre, Zectran at 1 pound per acre, and Telodrin at 1 pound per acre, gave control equal to or better than that obtained with a 1-pound-per-acre application of a DDT standard. Dimethoate, Zinophos, and heptachlor at 1 pound per acre gave poorer control than the DDT standard.

2. Beet Leafhopper-Curly Top on Tomato. In experiments in Utah various phosphorus insecticides showed promise in the control of the beet leafhopper on tomato and in the prevention of the spread of the virus of curly top disease to tomato. For example, in one experiment, curly top was reduced 40% by 4 applications of dimethoate, one in the starter solutions and 3 to the foliage at 2-week intervals. Similar results have been

obtained with phorate and Phosdrin. The work will need to be continued to develop a safe control program that can be depended upon for effectiveness and that can be recommended to growers.

3. Beet Leafhopper Control on Cantaloups. Field-plot experiments were conducted at Mesa, Ariz., for the control of the beet leafhopper and prevention of curly top in cantaloups. Previous experiments indicated that phorate as granules under the seed or as a foliage spray was effective against the leafhopper, and these treatments were used in this experiment. One, two, and three infestations of curly-top infective leafhoppers were effected by caging the insects on pretreated plants for 48 hours. Granules under the seed followed by one foliage spray on 2-leaf plants reduced losses in yield when plants were exposed twice to curly top-infective leafhoppers. Granules under the seed followed by two foliage sprays (one on 2-leaf plants and one on 4-leaf plants) reduced losses in yield when plants were exposed three times to curly top-infective leafhoppers, but under the conditions of this experiment granules under the seed without foliage sprays were ineffective. Multiple exposures to curly top-infective leafhoppers damaged plants and reduced yields more than one infestation in any stage of development. Small-plot experiments are currently under way in which a population of beet leafhoppers with a known percent of curly top-infective individuals has been retained on variously treated cantaloups from the early 2-leaf stage to the 6-leaf stage of plant development. This was done by caging entire plots and introducing the leafhoppers. Some of the plots contained favorable host plants in addition to the cantaloups, others did not. Effect on the plants and yield of melons are being determined.

4. Beet Leafhopper on Beans. Laboratory and field tests are being continued in an effort to find a control of curly top on beans by controlling the vector. The addition of beet juice or sugar to systemic insecticides of phorate, Phosdrin, or dimethoate has speeded up the mortality of leafhoppers and also reduced the amount of curly top over that obtained by the use of the insecticides alone. These results were obtained when the bean plants were infested with beet leafhoppers the day after they were sprayed. An effort is being made to determine how long the materials are effective. Many other materials are being screened in an effort to find a practical control of curly top on beans by controlling the vector.

5. Western Bean Cutworm. The western bean cutworm is one of the most threatening insect pests to the 125,000 acres of beans grown in southcentral Idaho. DDT gives very good control but may cause residues in meat or milk from drifting to pasture and hay crops growing in the same area. In an effort to find a less objectionable material, cutworm larvae reared in the laboratory from adult moths collected in blacklight traps were used in screening tests. Of many materials tested thus far, carbaryl, Zectran, Dylox, Perthane, endosulfan, carbophenothion, EPN, methyl ethyl Guthion, malathion, diazinon, and Bayer 25141 look the most promising.

6. Cowpea Curculio on Southern Peas. In field plot tests in South Carolina, dieldrin in granules showed the most promise, but was not significantly better than sprays of endosulfan, the currently recommended insecticide, or toxaphene or than a soil application of endosulfan in granules. A single soil application of toxaphene in granules was inferior.

7. Bean Insects. In large scale field tests in California on lima beans, carbaryl, toxaphene plus demeton, and dimethoate alone, gave the best control of lygus bug nymphs and greatest reduction in injury. Dylox, carbaryl, and Zectran, each in combination with demeton, also reduced nymph populations. Dimethoate showed promise against thrips. Carbaryl plus demeton and diazinon were the most effective against the two-spotted spider mite. In reducing injury to pods due to pod borer, carbaryl, endosulfan, and toxaphene were the most effective. In these experiments 28 of the most promising materials were tested. No control of the lima bean pod borer was obtained with dust mixtures containing pyrenone or pyrethrum and Bacillus thuringiensis. A carbaryl spray was the most effective.

A summary of 3-years' data on the effect of time of planting beans on pod borer infestations showed that in most years it is possible to reduce pod injury due to pod borer by planting beans between April 1 and May 1.

Of 18 experimental materials tested at Beltsville, Md., against the Mexican bean beetle, several gave promising results, including dimethoate and DDVP, which are relatively safe to use.

8. Leaf Miners. Of 38 compounds compared in laboratory tests in South Carolina in the spring of 1963, two experimental materials were more effective than naled--the standard--and will be field tested. In field tests dimethoate in foliage spray and soil drench and Guthion in foliage spray gave excellent control of leaf miners on tomato plants. A parathion spray was only partially effective, diazinon spray and phorate granules and Di-syston granules applied to the soil around plants were of no value under the existing extremely dry soil conditions.

Greenhouse experiments at Beltsville showed that three applications at 6- to 7-day intervals of DDVP aerosols or sprays of Zectran or diazinon destroyed larvae and adults on tomato and virtually cleaned up infestations during the active season of 1962.

9. Banded Cucumber Beetle. Of 94 compounds compared in laboratory tests in South Carolina, eight experimental materials were as toxic to the larvae as parathion--the standard. It is too early to tell whether any will prove to be of practical use. Larvae reared from beetles collected at Arnaudville and Baton Rouge, La., and Charleston, S.C., were about equally susceptible to aldrin, DDT, and Telodrin

In field tests at Baton Rouge, La., endosulfan spray and Telodrin granules gave promising results in the control of banded cucumber beetle larvae

feeding on the edible roots of sweetpotato. Telodrin also controlled the sweetpotato weevil in these tests. Neither insecticide is available for commercial use on sweetpotato. Surveys showed the numbers of banded cucumber beetle adults in sweetpotato fields did not correlate with damage to sweetpotato roots by larvae of these beetles. This lack of correlation may have been due to predators feeding on beetle eggs and to the fact that predators were less numerous in or near fields previously treated with persistent insecticides, such as heptachlor.

10. Banded Cucumber Beetle and Southern Potato Wireworm on Sweetpotatoes. In one 1962 experiment in South Carolina, in which injury was attributed to larvae of the southern potato wireworm and the banded cucumber beetle, DDT at 20 pounds per acre gave good control and was more effective than Telodrin at 1 pound or parathion at 6 pounds. None of these treatments caused any measurable effect on yields. In another experiment, DDT at 20 pounds per acre prevented injury by the southern potato wireworm. Parathion at 5 pounds and aldrin at 2 pounds per acre were ineffective. The failure of parathion is attributed to lack of adequate persistence to protect sweetpotatoes throughout the long growing season.

11. Squash Insects. Each compound tested in field plots in South Carolina gave adequate control of a light infestation of the pickleworm on yellow summer squash. The squash vine borer population was too low to give significant data, even though a count of eggs on the plants indicated that a good infestation should have occurred. In control of the melon aphid, Zectran and naled were superior to all other materials tested, but carbaryl, Bayer 44646, and lindane gave adequate control.

12. Aphids on Cabbage. Demeton, Di-syston, Phosdrin, phosphamidon, and dimethoate were the most effective materials tested in field plots in South Carolina for control of the cabbage aphid. These materials were superior to endosulfan, phorate, and a pyrethrum extract against that insect. Di-syston and phorate were superior to demeton and dimethoate in control of a root aphid, Pemphigus sp., which apparently did not harm the cabbage plants in the field under observation.

13. Cabbage Caterpillars. In South Carolina 17 experimental insecticides were highly toxic to the cabbage looper among 73 new compounds screen-tested in the laboratory. None were satisfactory in field tests although several, including Zectran, Bayer 44646, and Bayer 41831, gave good control of the cabbage looper and the fall armyworm. The experimental materials are either too toxic to warm-blooded animals to be of much promise or damage the plants. Continued studies will be necessary to develop satisfactory insecticides for use on cabbage and related crops within the last month before harvest.

A South Carolina strain of the cabbage looper proved less susceptible in laboratory tests than did a New York strain to naled, DDT, endrin, and parathion.

At Mesa, Ariz., field-plot tests showed that for use up to beginning of head formation, the following sprays gave good control of the cabbage looper: Toxaphene + DDT, Zectran, endosulfan, and American Cyanamid experimental compounds 43064 and 47031. A dust mixture of carbaryl with endosulfan also gave good looper control. For late use after the heads begin to form promising results were obtained with naled and American Cyanamid 43064 and 47031 sprays and with pyrethrum or pyrethrum + piperonyl butoxide dusts. Beet armyworms were harder to kill, and several of the newer materials gave better results than the standard toxaphene + DDT. These included Zectran and American Cyanamid 47031 sprays and the carbaryl + endosulfan dust mixture, although endosulfan alone was inferior.

In southern California 12 of the most promising experimental insecticides for cabbage looper control were tested in field plots with no outstanding control. Also, 7 different systemic insecticides including phorate, Di-syston, and dimethoate, were ineffective when applied as a sidedressing 5 inches to one side of each row.

14. Aphid Control in Cold Weather. Experiments in California on 7 leafy vegetables showed that at temperatures below 70° F., dimethoate and Isolan were more effective against aphids than parathion and other materials now recommended. In these tests parathion, endosulfan, naled, Guthion, and methyl Guthion did not give satisfactory control of the cabbage aphid and green peach aphid when temperatures remained below 70° F. Also, there was a tendency for residues of the phosphorus materials to persist much longer on the foliage than at higher temperatures. These results showed that growers in the winter who follow normal insecticide programs developed for warm weather may not only fail to control aphids but may also cause their crops to be contaminated at harvesttime with excess residues of insecticides. Special programs need to be developed for aphid control on winter vegetables during cold weather. These results in California were supported by similar results in field tests with parathion on lettuce in Arizona and on kale in Maryland.

C. Insecticide Residue Determinations

1. Minimum Waiting Periods. To obtain residue data needed to establish minimum waiting periods from the last application of insecticides on vegetables until harvest, and to form a basis for the development of safe insecticide dosages and application programs, numerous samples of vegetables from experimental plots at Riverside, Calif.; Mesa, Ariz.; Logan, Utah; Yakima, Wash.; Charleston, S.C.; Tifton, Ga.; and Beltsville, Md., were analyzed by chemists at Yakima, Wash.; Tifton, Ga.; and Beltsville, Md., and by various insecticide companies. Samples from 10 different crops from Riverside, for example, were analyzed at Yakima for residues of 6 different insecticides and the results correlated with various factors, such as temperature, rainfall, dosage, and the time interval from application to harvest. The results of these studies have been of great value in the development of recommendations of safe and effective uses of insecticides.

During the past year residue studies have led to the general revision of the USDA recommendations relative to the use of parathion on winter vegetables such as celery, cabbage, broccoli, and related crops to take into account the greatly increased persistence of parathion residues at temperatures below 70° F. The revised recommendations are given in USDA Agriculture Handbook No. 120 "Insecticide Recommendations of the Entomology Research Division for the Control of Insects Attacking Crops and Livestock for 1963."

2. Telodrin. At Tifton, Ga., sweet corn treated with 0.5 to 2 lb. of Telodrin per acre was analyzed. Initial residue deposits on leaf and stalk samples ranged from 1.9 to 8.4 p.p.m. but decreased rapidly after 24 hours. The maximum after 21 days was 0.7 p.p.m. Initial residues on the husks ranged from 1.8 p.p.m. to 2.0 p.p.m. Only the 2 lb.-per-acre level showed any material (0.01 p.p.m.) on kernels and cob and none could be detected 24 hours after application.

3. Phorate Residues in Seedling Cantaloup Plants Affected by Placement in Soil. Field plot experiments were conducted at Mesa, Ariz., to determine the most effective placement of phorate granules with respect to the seed in the control of the beet leafhopper on cantaloup. Plants grown in plots receiving various granular placements were harvested in the 2-leaf stage and submitted for phorate analysis. The greatest amount of phorate was recovered from granules intermixed with the seed, but this treatment was unsatisfactory because of a reduction in plant stand. The next greatest recovery of phorate was from the placement of granules 2 inches below the seed. Significantly less amounts of phorate were recovered from the placement of granules 1 inch below the seed, one-half inch below, and 1 inch below the seed and 2 inches toward the water furrow.

4. DDVP Residues. In Maryland DDVP residues on greenhouse tomato fruits decreased from a range of 0.5 to 1.3 p.p.m. on ripe fruits harvested one hour after treatment with DDVP aerosol to none on ripe fruits harvested 5 days later. On lettuce foliage the residues ranged from 1.4 to 2.5 p.p.m. after 1 hour and were 0.2 after 5 days. The treatments were effective against aphids, whiteflies, spider mites, cabbage loopers, and leaf miners.

5. Temperature Affects Disappearance of Parathion Residues. In Maryland, the laboratory study on the effect of temperature on the rate of disappearance of parathion residues was continued. Beans were grown in controlled temperature chambers and variables other than temperature were eliminated as completely as possible. A measured amount of parathion was applied in emulsion form to each leaf to insure uniform amounts at the beginning of the experiment. One hour after application the deposits present were about 700 to 800 micrograms of parathion per leaf. At 50° C. this decreased to about 570 micrograms per leaf after 3 days and 100 after 21 days. At 70° C. the parathion decreased to 236 micrograms after 3 days and 7 micrograms after 21 days.

D. Biological Control

1. Cabbage Looper and Other Caterpillars on Cole Crops. In further studies in South Carolina, the pathogen Bacillus thuringiensis gave excellent control in field plots of the imported cabbageworm and diamondback moth on cabbage and partial control of the cabbage looper and fall armyworm. The addition of corn oil again tended to increase the kill of caterpillars given by the pathogen. Even though the Bacillus did not give as high reduction of the looper population as did parathion and naled, which are currently recommended for control of the looper on cabbage, the pathogen was as effective as these insecticides in preventing damage to the plants by the insect. The pathogen acts as a repellent to feeding by the caterpillars, as well as being toxic to them. Even though B. thuringiensis proved as effective as parathion and naled in preventing injury by the cabbage looper in 1963 spring-season tests, six weekly applications of these materials did not give adequate control of that insect. A new commercial suspension formulation of B. thuringiensis, known as Thuricide 90T, did not prove any more effective against the cabbage looper in laboratory and field tests in 1963 than did the most promising of previously available wettable powder formulations of the pathogen. Two commercial formulations of B. thuringiensis gave faster kill of a laboratory-reared New York strain of the cabbage looper than of a Charleston, S.C., strain. Fifty-seven percent of third-instar loopers were killed in 72 hours after having fed on collard foliage that had been dipped in a concentrated suspension of parasporal crystals of B. thuringiensis (G2), furnished by the Insect Pathology Laboratory, Beltsville, Md. Two dilutions of ultraviolet irradiated parasporal crystals furnished by the Laboratory were apparently not pathogenic to third-instar cabbage looper larvae in laboratory cages.

Laboratory tests in South Carolina during 1962 and 1963 indicated that a Charleston, S.C., culture of a nuclear polyhedrosis virus was more toxic to Charleston cabbage looper larvae than cultures from California, New York, Texas, and Virginia. A combination of the Charleston virus culture and Thuricide 90T, a newly-introduced commercial suspension formulation of the pathogen Bacillus thuringiensis, was as effective against the cabbage looper as parathion in 1963 field tests. The pathogen combination gave adequate control when applied 12 times at intervals of 3 or 4 days, but not quite adequate when used weekly. The virus culture lost its toxicity to cabbage loopers much more rapidly when exposed to outdoor weathering than when kept indoors.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sex Lure in Banded Cucumber Beetle. A natural sex attractant produced by females of this insect, usually by the time they were 10 days old, was demonstrated in South Carolina to be capable of luring males of the species from distances up to 49 feet. Unmated females remained attractive to males as long as 79 days. Most females ceased to be attractive after one mating, and none were attractive after two matings. The attractant was extracted

from female abdomens with alcohol. Extracts of the heads and thoraces and of filter paper on which females had crawled gave negative results.

2. Sterilization of Banded Cucumber Beetle. In laboratory cage studies, virgin males and females of this beetle, approximately 5 days old, were mated after having fed on collard foliage which was dipped in metepa solutions (in .05% Triton X-100) at concentrations of 0.1, 0.2, and 0.5%. Virgin males and females were also fed on foliage dipped in the 0.2% metepa solution and then mated with untreated virgin females and males. The insects were allowed to feed on the treated foliage for 48 hours, and then on untreated foliage for 30 days. Ninety to 100% of the eggs obtained from treated females mated to treated males failed to hatch. The three concentrations were about equal in effectiveness. Males were more effectively sterilized than females. Only 10% of the eggs laid by untreated females mated to treated males hatched; whereas, 90% of the eggs laid by treated females mated to untreated males hatched. In another test virgin males approximately 3 days old were dipped in a 1.0% metepa solution and mated with virgin females. Only 4% of the eggs deposited by these females hatched.

3. Winter Survival of Sterilized Mexican Bean Beetle. In experiments at Beltsville adult males and females maturing in September and early October were dipped in 0.25 or 0.5% apholate, marked with enamel paints for identification, and placed in hibernating cages with untreated beetles. Winter survival and spring emergence of beetles in all three groups were similar (about 15%). This treatment had been shown in laboratory tests to render the beetles sterile.

4. Sterilization of Cabbage Looper. In studies of the sterile-male technique at Riverside, Calif., the cabbage looper males were sterilized by exposure to glass that had been sprayed with an 8% tepa solution. The spray residue on the inside surface of glass jars in the laboratory were effective for 18 days. Exposure of males to freshly dried residues for 5 minutes resulted in 16% sterile eggs, while a 45-minute exposure gave 93% sterile eggs and a 2-hour exposure gave complete sterility. Residues from 16% metepa gave similar results. Promising results were obtained in the self-sterilization of the looper moths by attracting them to blacklight bulbs surrounded by a celluloid shield coated with residues from 8% tepa solution. In a walk-in cage containing four 20-foot rows of cabbage infested with 30 pairs of 1-day-old moths 95% fewer larvae were produced than in similar cages equipped with lights without tepa.

5. Sterilization of Drosophila. In Maryland studies, complete sterility of Drosophila melanogaster eggs resulted when virgin females were mated with newly emerged males that had fed for 20 hours on freshly-prepared sugar-yeast bait containing 1% apholate. However, only partial sterility resulted when virgin females were mated with males that had fed for the same period on sugar-yeast-apholate bait that had aged 1 to 5 days. The percentages of emergence of adults from eggs laid in these pairings were 22 for 1-day-old

baits, 31 for 3-day-old baits, and 40 for 5-day-old baits, compared with 71 for checks where the males received no apholate.

Male D. melanogaster mated less readily and less frequently immediately after exposure to 16 kr of gamma radiation than did untreated males. The period prior to first copulation for irradiated (16 kr) males was over 3 times that of untreated males for the first mating, and over 5 times the precopulation period of untreated males before the second mating. A 24-hour recovery period after exposure to 16 kr resulted in normal mating behavior and frequency. After this recovery period, there was little effect on mating competitiveness based on tests where irradiated (16 kr) males and untreated males were confined in ratios of 1:1, 5:1, 10:1, and 20:1.

F. Evaluation of Equipment for Insect Detection and Control

1. Electrostatic Duster. Studies conducted in cooperation with ARS agricultural engineers at Tifton, Ga., indicated that plants dusted by use of an electrostatic duster that produced either positive or negative charges on the particles, had about 57% and 36%, respectively, greater residues than plants dusted with uncharged particles, even 48 hours after application. The positively charged treatment appeared to be slightly better than the negatively charged treatment during the same period.

2. Improvement of Corn Earworm Control Methods. Agricultural engineers and entomologists at Tifton, Ga., found that superior spray coverage and corn earworm control on sweet corn could be obtained when sprays were applied at 100 p.s.i. with fan type nozzles placed 90° to the plant. Methylene blue was a satisfactory dye indicator to study spray residue deposits.

3. USDA Developed Sprayer Now in Commerical Production. A commercial version of the USDA trailing boom sprayer developed at Forest Grove, Oreg., by engineers of the Agricultural Engineering Research Division, in cooperation with the entomologists, is now being manufactured by Rear's Manufacturing Company, 755 River Road, Eugene, Oreg., as a Pul-Tank trailing boom spraying unit. It is trailer-mounted with a ground clearance of 30 inches and is made in 6- and 8-row models. A short coupling device on the Pul-Tank trailer allows it to follow the tractor tracks and permits short turns at the headlands of a field. The trailing booms are lifted by partially rotating the draw boom. As the draw boom is rotated, the outer portions are lifted up and fold upright, all by means of a hydraulic cylinder and cable arrangement. The Pul-Tank has a capacity of 300 gallons. The spray pump is driven by power take-off from the tractor. Each row is covered by 5 cone-type spray nozzles. This commercial unit proved exceptionally useful to Oregon broccoli growers in the control of cabbage caterpillars and aphids in 1962.

4. Increased Power of Airplane Sprayer Changes Spray Pattern. When the Rawdon T-1 at Forest Grove, Oreg., was equipped with a 150 hp., engine, a non-symmetrical nozzle arrangement did not improve the uniformity of the

spray deposit across the treated swath over that obtained with a symmetrical arrangement. However, since the installation of a 250 hp., engine in this airplane, there is a noticeable difference in the shape of spray deposit patterns from the asymmetrical and symmetrical nozzle arrangements. The symmetrical arrangement produced a pattern triangular in shape, while the non-symmetrical arrangement produced a more trapezoidal shaped curve. The non-symmetrical arrangement also left a typical low deposit area near the swath center while the symmetrical arrangement did not have this low deposit area. This work was in cooperation with the Agricultural Engineering Research Division.

5. Application of Insecticides with Ground Equipment. In exploratory field-plot tests in South Carolina in which only one application was made of each insecticide, no significant difference in cabbage looper and diamondback moth reduction was found between toxaphene (at 2.5 lb./a.) and naled (at 2 lb./a.) applied either with a 5-nozzle per row trailing boom or 3- and 5-nozzle per row conventional booms. Neither were any significant differences in caterpillar control obtained from application of the two insecticides in 10, 20, and 100 gallons of water per acre, applied with different types of booms. There were tendencies for the 20 and 100 gallonages applied with 5-nozzle booms to be most effective. The trailing booms used were designed by USDA agricultural engineers at Forest Grove, Oreg., and manufactured there under their supervision.

G. Varietal Evaluation for Insect Control

1. Corn Earworm and Fall Armyworm on Sweet Corn. At Tifton, Ga., irradiation trials were unsuccessful in producing corn mutagens with increased earworm resistance. Earworm resistance varied with planting date even under the same infestation level. Ear penetration by earworm larvae varied significantly with the time of infestation after pollination. Preliminary tests indicated no differences in oviposition response in relation to the color of the corn silks. Bioassay of extractions of freshly harvested plant material have indicated that differences exist among inbreds, in leaf tissue susceptibility to fall armyworm feeding, and in antibiosis of silks to corn earworm larvae. Inbreds with foliage resistance against the fall armyworm do not necessarily have resistance against the corn earworm.

At West Lafayette, Ind., 404 entries of experimental sweet corn hybrids were rated for earworm resistance. The hybrid 363-1-1 X 379-1-1 was not damaged and was rated as being the most resistant and promising source of resistant germ plasm. Several other hybrids were rated as extremely resistant. Earworm larvae were able to mature on the silks alone on several hybrids and seldom reached the tip or kernels of the ears. Inbred 259(13) 1-2-1-1-2-1-1-1-1-1-1, one of 19 white sweet corn inbreds tested, was very resistant to corn earworm but had poor quality. Of 86 yellow sweet corn inbreds tested, 390(9)2-1-3-1 was rated as the most resistant. This inbred has shown good resistance in the past and transmits resistance to its progeny. Twenty-one other yellow inbreds were rated as resistant to the corn earworm.

2. Southern Potato Wireworm on Sweetpotatoes. Sweetpotato breeding Line L3-64 in South Carolina was the least susceptible to injury by larvae of this insect in field trials of several lines. Line L3-64 also showed considerable resistance to banded cucumber beetle injury in Louisiana.

H. Insect Vectors of Diseases

1. Aphid Control and Its Relation to Lettuce Mosaic Virus. At Mesa, Ariz., good control of the green peach aphid in lettuce was obtained in experimental plots with phorate granules one-half inch and 2 inches under the seed. Dimethoate sprays on young plants also gave good control, but winged aphids from an adjacent older lettuce planting eventually infected the entire experimental planting with mosaic. However, a significantly heavier yield of lettuce was obtained from treated plots than from the untreated check, even though symptoms of disease did appear in the treated areas.

2. Aphids Correlated with Mosaic in Lettuce Fields. Thirteen lettuce fields in the Salt River Valley of Arizona were studied to determine aphid populations and the resulting crop loss from lettuce mosaic. Losses in yield from lettuce mosaic varied from 2.2% up to 21.2%. Early plantings showed less damage than later ones. Fields with very few or no aphids until after the plants had 10 or more leaves had little mosaic at harvesttime. No correlation was found between the presence of weeds and lettuce mosaic.

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AREA NO. 2. POTATO INSECTS

Problem. The profitable production of high-quality potatoes demanded by the consumer necessitates the control of injurious insects. Available control methods involve the use of insecticides, some of which are not adequately effective because of resistance of the insects to them. Certain insecticides may leave undesirable residues on or in potatoes. There is, therefore, continuing need for research to develop safe, effective, and economical methods of control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the ecology and biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Growing concern over problems associated with insecticides, which may include adverse effects from residues in the soil, contamination of non-target areas and interference with the work of natural enemies of insect and mite pests, makes it imperative that an increasingly strong research effort be directed to the development of non-chemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

USDA PROGRAM

A continuing program involving basic studies on the biology, ecology and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control is conducted by the Department at Yakima, Wash.; Orono, Me.; Beltsville, Md.; and Charleston, S.C., in cooperation with the respective State Experiment Stations, the Washington Department of Agriculture, the Washington State Potato Commission and industry.

The Federal scientific effort devoted to research in this area totals 6.3 professional man-years. Of this number 1.9 is devoted to basic biology and physiology; 2.1 to insecticidal and cultural control; 1.0 to insecticide residue determinations; 0.3 to biological control; 0.2 to insect attractants; 0.1 to varietal evaluation for insect resistance; 0.4 to insect vectors of diseases; and 0.3 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology and Physiology

1. Wireworms. These insects appear likely to become the most destructive pests of vegetables and other crops in the million-acre Columbia Basin Irrigation District of Washington during its rapid transformation from semi-desert to irrigated farmland. Since 1950, the indigenous Great Basin wireworm (Ctenicera pruinia) has decreased in abundance because it thrives on bunch grass in non-irrigated grain lands and is not adapted to irrigation conditions. Although this wireworm is destructive to potato seed pieces and developing tubers during the first year or so after a field is first irrigated, research has shown that few can survive more than three years of irrigation farming. The sugar beet wireworm (Limonius californicus), Pacific Coast wireworm (L. californicus), and Columbia Basin wireworm (L. subauratus) have been present in older irrigation districts of Washington since the early twenties and are likely to replace the Great Basin wireworm in the newly irrigated areas where they can be very destructive. In recent years, the Pacific Coast wireworm has moved into the Columbia Basin, where the light, sandy soil is especially favorable to it. Losses to potato growers by this species, first reported in 1959, have increased in severity and become more widespread each year. The Columbia Basin wireworm is now highly resistant to aldrin, although this material has never given consistent control at registered rates. In 1962, a three-pound-per-acre application failed to prevent a total loss of potatoes in some fields. In one case where the crop was quarantined because of aldrin-dieldrin residue in the tubers above the legal tolerance, a gas chromatographic analysis showed excess insecticide residues in the wireworm damaged tubers.

In South Carolina all attempts to get laboratory-reared adults of the southern potato wireworm to deposit fertile eggs in the laboratory have failed. Wild adults caught in black-light traps lay fertile eggs freely. Most of the eggs are laid at night and it is at night that the adults come to light traps, mostly before 8:30 p.m. The recent discovery of a method of sexing the insect in the pupal stage has made it possible for the first time to isolate and pair virgin male and female adults without causing physical damage. However, all attempts to observe attraction between the sexes in the laboratory have failed. The damage to crops caused by this wireworm continued to spread in the South. Spread of this insect northward appears to be limited by its inability to survive for long in subfreezing temperatures. Subnormal temperatures at Charleston in December 1962, for example, killed about 67% of the wireworms in untreated plots under observation.

2. Foxglove Aphid. In Maine, results of intensive studies over a period of 5 years on the biology of the foxglove aphid have been assembled and prepared for publication as a Technical Bulletin of the Department. Prior to 1956 when the primary host of this aphid in Maine was discovered to be

hawkweed, the source of the large numbers found on potatoes each spring was a mystery. This insect is one of the 4 aphids that attack potatoes in the Northeastern States and cause injury by their feeding punctures, toxic secretions, and by spreading virus diseases. These and less intensive studies over the past 20 years show that in New Jersey and southward the foxglove aphid continues to feed on available host plants and reproduce parthenogenetically, giving birth to living young throughout the year. Some are wingless, whereas others are winged and fly to other hosts. However, north of New Jersey a sexual generation of males and females develop on hawkweed in October which produces eggs that are able to survive the severe winters. In Maine, the eggs hatch in early May and produce winged asexual females that mature from early June to late July and migrate to the potato fields.

3. Six-Spotted Leafhopper. Field cage studies verified earlier suspicions that this insect overwinters to some extent in the egg stage in barley plants in eastern Washington and that the large populations of the leafhopper found there during the summer are not dependent upon spring migrations from the South. The common weed, horsetail (Conyza canadensis), was an abundant overwintering reservoir of aster yellows during the winter of 1961-62 and apparently was responsible for more than usual abundance of aster yellows on carrots and other susceptible crops.

4. Seed-Corn Maggot. Unusually large numbers of puparia of this insect were found in the soil of several Columbia Basin, Washington, fields screened during the early spring of 1963. Later, many fields were planted with freshly cut potato seed pieces during the rainy week of April 21, and a few fields required replanting because of maggot injury and associated rotting of the seed. In fields where seed lots had apparently suberized somewhat (cut surfaces healed) before planting, the maggots had entered through wounds made during the planting process by the tic-type planters used. Heavy maggot populations developed frequently in potato seed pieces in fields where heavy green manure crops had recently been plowed down.

B. Insecticidal Control

1. Green Peach Aphid. In Washington, experiments started in 1962 on the control of the green peach aphid and completed in 1963 with the evaluation of chronic (tuber perpetuated) leaf roll showed a marked decrease in the number of plants that became infected with this aphid-borne disease as the number of applications of the aphicides increased from 1 to 4. The percent of chronic leaf roll was reduced from 42 to 7 by the control of the aphid with endosulfan, 48 to 9 with Meta-systox, and 24 to 14 with endrin. Previous study at Yakima, Wash., showed that the effectiveness of band applications of 2 pounds of Di-syston or phorate per acre in granules to light soil, or 3 pounds per acre to heavier soil in the planting furrow in March or April did not last until the main summer flight of aphids. Tests in 1962 showed that the period of good protection against establishment of aphid colonies could be prolonged by delaying the soil band application

until about May 15 when the insecticide can be conveniently mixed with part of the fertilizer usually sidedressed to the crop at that time. Residues of Di-syston were below the tolerance where treatments were made 90 days prior to harvest.

2. Aphids. In Maine, low aphid populations at Presque Isle made it difficult to evaluate control methods; however, 1 pound of Di-syston per acre in the planting furrow continued to be effective and was superior to 1 pound of Menazon or 2 of phorate. Three weekly applications of insecticide to the foliage, starting in mid-June, provided generally less effective all-season control of the aphids than did applications made whenever aphids could be found on 50% of the plants by examining only 3 leaves per plant, one each from the top, middle, and bottom of the plant. Using the latter criteria, only 1 application of Meta-systox at 3/4 lb. per acre was required, as compared with 2 applications for parathion, endothion, or endrin at 1/4 lb. per acre. Aphids were not sufficiently abundant to cause feeding damage that would be reflected as reduced yield of tubers.

3. Southern Potato Wireworm. In South Carolina, exploratory tests with 34 new materials revealed 4 worthy of further tests, adding to the list of experimental materials having promise for controlling this wireworm. In the meantime, the recommended parathion and diazinon treatments continued to give good protection of potatoes under most conditions. However, there was some evidence of resistance on the part of the wireworm to parathion. Of the new materials that show promise phorate could be recommended were it not for the fact that residues may be deposited in the tubers under some conditions and there is no established tolerance. A similar material, Di-syston, has a tolerance in potato but appears to be inferior against this particular insect. The other promising materials are strictly experimental. Information on the biology of this insect and how to control it on potatoes has been prepared for release to growers as a USDA leaflet.

C. Insecticide Residue Determinations

1. Dieldrin Residues in Potatoes. As a result of seizures by the Food and Drug Administration in the Pacific Northwest of potatoes containing aldrin-dieldrin residues in excess of the tolerance of 0.1 p.p.m., analyses were made by the chemists at Yakima, Wash., by gas chromatography of a large number of samples of potatoes and soils in which they were grown. The results of these analyses indicated in general that the application of 5 lb. of aldrin per acre as a granulated formulation broadcast and cultivated into the soil under some conditions may result in aldrin-dieldrin residues in the potato in excess of tolerance. Similar applications of 6 lb. of dieldrin per acre did not result in excess residues. In some instances grower applications of 2 to 3 lb. of aldrin per acre applied as a sidedressing resulted in residues in excess of the tolerance. At Beltsville, Md., excess residues also were found in potatoes grown in Maine in soil treated before planting with 3 pounds of aldrin per acre. As a result of these studies USDA has ceased to register or recommend the

use of aldrin in the soil for insect control on potatoes. Consequently, stocks of Farmers' Bulletin No. 2168 "Controlling Potato Insects," which contained recommendations for the use of aldrin in the soil for control of potato insects, were destroyed and a revision printed without such recommendations.

2. Di-syston Residues in Potatoes. Potatoes were treated with 2.0, 2.5, and 3.0 pounds of actual Di-syston per acre as a sidedressing. Samples taken 78 to 96 days after treatment contained from 0.04 p.p.m. to 0.24 p.p.m. of Di-syston, which is well below the tolerance.

3. No Dimethoate Residues from Foliar Treatment of Potatoes. At Yakima, Wash., no measurable dimethoate residues were found in potatoes that had received 5 foliar sprays at 2-week intervals using 1/4 lb. dimethoate per acre per application.

D. Biological Control

1. Aphids. In Maine a long-term survey study was continued on the insect parasites, predators, and fungus diseases of aphids affecting potatoes. Quantitative records of the abundance of each type of control agent in plots and fields of potatoes at Presque Isle and to some extent elsewhere in Northeastern Maine were accumulated and the parasites and fungi were identified, the latter by the California Agricultural Experiment Station. While neither the parasites nor the predators appeared to exert a substantial effect upon aphid population trends on potatoes, fungus disease had a mid- and late-summer effect with peak abundance of the potato aphid substantially below the expected abundance in the absence of fungus action. In 1962 the predominant species of fungus was Entomophthora ignobilis. The most important insect predators were the lady beetles, Coccinella transversogutatta and Hippodamia 13-punctata tibialis. The most common species of parasites in 1961 were Aphidius nigripes and Praon spp. About 36% of the primary parasites were infested with hyperparasites in 1961. One shipment of a parasite, Aphidius avenae, from France was liberated in a field of aphid-infested potatoes in Maine but the evidence thus far indicates the parasite has not become established.

E. Insect Vectors of Diseases

1. Aphids. Tuber samples from plots sprayed in 1961 were planted, grown, and observed in 1962 at Presque Isle, Me., for symptoms of leaf roll to determine what effect the spray treatments had upon seasonal spread of this aphid-borne virus disease. Endosulfan, endrin, and Menazon applied for aphid control appeared to be effective in preventing spread of leaf roll on Katahdin potatoes. There was virtually no spread of the disease in Katahdin, Green Mountain, or Chippewa potatoes where an application of Di-syston at 1 pound per acre was made in the planting furrow, whether the abundance of infected tubers planted was 1% or 4% of the stand. Katahdin has some resistance to leaf roll under field conditions; and Green Mountains

and Chippewas are rather susceptible to the disease. Although little spread occurred in untreated potatoes, the amount was correlated with the abundance of infector plants and the aphid-days of infestation to which the plants were subjected. Virtually all of the spread was by aphids that developed within the plots; very little if any was brought into the plots by winged, incoming aphids. Preliminary greenhouse readings of leaf roll from samples of potato tubers at Presque Isle indicate that no protection from infection by viruliferous green peach aphids was afforded caged plants of the Kennebec variety in 1962 when they were sprayed with water mixtures of compounds that possessed antifeeding properties or repellency for the green peach aphid. However, there may have been some reduction in infection when the plants were sprayed with mixtures containing 2,000 p.p.m. of chlorocholine chloride, Sarcocyl, or of Aerosol OT before being infested for 24 hours with the viruliferous green peach aphids.

2. Six-Spotted Leafhoppers. Aster yellows is a cause of an internal discoloration of potatoes in the West. Results of an experiment in Washington verified suspicions formed several years ago that an internal grade defect resembling the net necrosis caused by leaf roll virus, can result from an infection of the California strain of aster yellows. Although workers in New York, Pennsylvania, and Colorado have reported aster yellows responsible for internal discoloration of potato tubers, this is the first record for the Far West. In this experiment, a number of Montana-grown certified seed potatoes were cut and planted in clay pots in April and placed in the isolation greenhouse. Cages were placed over each plant and on May 1 viruliferous six-spotted leafhoppers (Macrosteles divisus Uhl.) were removed from a diseased Erigeron canadensis plant and placed in each cage. The leafhoppers were allowed to feed for three weeks and then killed by fumigation. Internal discoloration resembling that caused by leaf roll was found at the stem ends of the new-crop tubers when examined August 31.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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Insect Vectors of Diseases

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AREA NO. 3. DECIDUOUS FRUIT, TREE NUT, GRAPE AND BERRY INSECTS

Problem. Insects and mites are important limiting factors in the production of high quality fruits, nuts, grapes and berries. These pests shorten the profitable life of the trees, vines, or plants, and reduce the yield or lower the quality of the crop. Certain insects and mites transmit diseases that affect adversely the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. Biological, cultural and other non-chemical methods of control are only partially effective. Consequently, dependence must be placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical and safer insecticides; and an urgent need, because of growing concern over the use of insecticides, for intensified research on alternative types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and growth-affecting materials, including chemosterilants. More research is needed on integrated chemical-biological control programs with emphasis on less intensive spray programs, so that the maximum benefits from parasites, predators and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, to discover the insect and mite vectors of the diseases and to determine their host preferences, ranges, and habits. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

USDA PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of grower's problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on berry insects at Beltsville, Md., and Riverside, Calif., the latter in cooperation with the California Experiment Station. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Corvallis, Oreg., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the

respective State Experiment Stations and the Crops Research Division.

The Federal scientific effort devoted to research in this area totals 21.1 professional man-years. Of this number 2.4 is devoted to basic biology and nutrition; 5.6 to insecticidal control; 3.4 to insecticide residue determinations; 0.6 to biological control; 3.3 to insect sterility, attractants, and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 3.5 to insect vectors of plant virus diseases; and 1.3 to program leadership.

Additional research (3.5 professional man-years) is in progress under grants of P.L. 480 funds to the Institute of Pomology, Skierniewice, Poland, for studies of the differences in susceptibility and in cholinesterases in various species of spider mites as influenced by acaricides and for studies on the biological control of aphids and scale insects on deciduous tree fruits and effects of pesticides on natural enemies. A portion of a grant of P.L. 480 funds to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan (10 professional man-years) for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan is applicable to insects affecting deciduous tree fruits.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology and Nutrition

1. Deciduous Fruit and Nut Insects. Limited studies of the biology of the pear psylla, blueberry tip borer, cherry fruitworm, mirids that feed on pecan, periodical cicada and lesser peach tree borer were made as a basis for improving or developing more appropriate control recommendations. Continued study of the movement of the pear psylla in Washington confirmed previous findings that this insect migrates mostly during the fall and early spring months. Psylla adults overwinter on fruit trees other than pear and on plants growing considerable distances from the pear orchards in which the psylla were produced. In the spring these psylla may move to pear orchards located some distance from the orchards in which they were produced. In Ohio information was obtained on the seasonal history and habits of the blueberry tip borer and cherry fruitworm in blueberries as a basis for determining the status of these insects as pests and for developing control recommendations. In the South several species of mirids, particularly Neolygus caryae and Plagionathus ablatus, sucking insects which appear in large numbers on the developing pistillate bloom of pecans, have been thought to be responsible for loss of young nuts on which they feed. In Georgia these mirids laid eggs in terminal growth and fed to some extent on small nuts as well as on leaflets and new terminal growth, but preliminary tests indicated they are not responsible for crop losses.

In studies of the periodical cicada in Indiana it was found that the adults of this insect moved into orchards from surrounding woodlands when the urge to oviposit reached a peak. The cicadas were able to lay numerous

eggs before they were killed by insecticide applications to the orchards. This emphasizes the need to treat surrounding woods before cicadas move into orchards. It was also found that the lesser peach tree borer starts to emerge about a month earlier than formerly believed, indicating that control measures should be initiated earlier than commonly recommended. In West Virginia analyses of sprayed apple leaves showed that spray schedules containing DDT or carbaryl (Sevin) were followed by consistently higher levels of leaf sugar in the leaves than spray schedules containing other materials. This condition was correlated with higher mite populations.

It is essential that large numbers of test insects be available at all seasons of the year to facilitate the conduct of an uninterrupted research program. To raise normal insects cheaply and in large numbers requires knowledge of their physical and nutritional requirements. In Indiana an artificial diet that was inadequate for the production of normal codling moths became satisfactory when ascorbic acid was added. Studies to adapt this diet to large-scale laboratory production of the codling moth are underway. In Washington production of the codling moth was increased from 1.2 cocoons per thinning-size apple to 5 by cutting the thinning-sized fruits into quarters or eighths and coating the sections with paraffin to prevent their premature decay. Preliminary studies of diets for rearing the hickory shuckworm, pecan leaf casebearer and fall webworm, to provide a continuous supply of these insects for studies on their control on pecans in Georgia were unfruitful. Ability to mass produce insects is a prerequisite for research on the sterile male release method of population suppression.

2. Insect Vectors of Viruses. At Corvallis, Oreg., biological studies were conducted with Scaphytopius acutus, an established leafhopper vector of X-disease virus of stone fruits. The object was to determine whether there are two strains of this species, one obligated to enter diapause during the winter and the other capable of breeding continuously. Critical taxonomic study showed that the leafhopper not requiring a diapause was another species, Scaphytopius delongi, that occurs frequently in populations with S. acutus. The fact that S. acutus has been handled in pure culture in many or most instances in the past indicates that it is a vector of X-disease. The status of the newly detected S. delongi needs to be investigated.

In California a repetition of an early summer survey for the peach mosaic transmitting eriophyid mite, Eriophyes insidiosus, in the central part of the State again indicated that the vector is not present in that area. Thus, the known range of the vector is south of districts producing the preponderance of California's peaches. Less than 2,500 acres of 118,000 commercial peach acres in California are in the territory known to be infested by the virus-carrying mite.

Several species of eriophyid mites in the genus Eriophyes related to the demonstrated mite vectors of peach mosaic and cherry mottle leaf viruses have been detected. These have been found on stone fruit trees, including wild, native Prunus, pear, apple, and several species of perennial plants in the proximity of stone fruit orchards. The mites are being described and named. They deserve attention in future studies that may be initiated to find vectors of several other deciduous fruit tree viruses.

B. Insecticidal Control

1. Codling Moth. The demonstrated ability of the codling moth to develop resistance to insecticides is responsible for the need to continue studies of promising new insecticides and studies that may lead to the more effective integration of chemical and non-chemical methods for controlling this insect.

Guthion and carbaryl alone or in combination continued to give effective codling moth control. None of the new materials tested in field plots in Washington and Indiana and bioassayed in the laboratory was equal or superior to these materials. However, Bayer 39197, 41831 and 47940, General Chemical GS-3707, Thiodan II, and Stauffer R-3413 gave economic control in orchard plots in Washington; and American Cyanamid 38023, Bayer 44646 and 37344, and Zectran gave good control in field-laboratory tests in Indiana. In Indiana there was an indication that the carbamates, Bayer 37344 and Zectran, would reduce the set of apples when applied at or within 30 days after petal fall. In laboratory screening tests in Washington and Indiana 13 compounds were found worthy of further study. Of these Bayer 41831 and 46676, General Chemical CPD-4072, Hercules 7845C and Monsanto CP-40507 were superior to Guthion in toxicity to newly hatched codling moth larvae. In tests in Indiana the addition of summer oil increased the effectiveness of carbaryl against the codling moth.

Increasing support is being obtained for the idea that less intensive spray programs than those now commonly recommended may give adequate control of the codling moth and associated insects. Further studies in cooperation with commercial apple growers in the Yakima Valley, Wash., showed for the third consecutive year that economic control of codling moth and mites may be possible with two applications of Guthion and an acaricide. In an orchard in Indiana in which the 1961 crop averaged 176 worm holes per 100 apples, Guthion spray programs reduced the number of worms to less than 1 per 100 apples in 1962. Lengthening the interval between applications after the second cover spray from 10 to 16 or 26 days resulted in little loss in effectiveness. Fruit free of insect injury averaged 99.5% in the block sprayed 11 times at 10-day intervals, 96.4% in the block sprayed 8 times at 16-day intervals, and 93.5% in the block sprayed 6 times at 26-day intervals. In the last block injury due to the codling moth amounted to only 0.9 worm and 4.9 stings per 100 apples.

In continued studies of the effectiveness of concentrated sprays for controlling codling moth on apple, 12 pounds of 25% Guthion wettable powder per acre applied in 800, 400, 200, 100, and 50 gallons per acre with a conventional air blast sprayer, and in 60 gallons per acre with a sprayer designed for concentrate spraying, were equally effective in controlling the codling moth in the Yakima Valley in Washington. Chemical analyses for Guthion residues on foliage following spray applications showed that deposits at the 6-, 12- and 18-foot heights were comparable at application rates of 800 and 400 gallons per acre. When application rates were decreased to 200, 100 and 50 gallons per acre, deposits at the 18-foot height remained about the same but at 6- and 12-foot heights there was a gradual increase with decreases in gallonage.

2. Orchard Mites. Strains of orchard mites resistant to approved miticides are widespread. None of the recommended materials can be depended on to control all strains. This situation has required an accelerated program of screening of new insecticides, antibiotics, and other types of compounds that might inhibit mite activity and development and an intensification of studies of factors responsible for fluctuations in mite populations.

In orchard tests in the Yakima Valley, Washington, Kelthane and tetradifon, the standards for comparison, gave effective control of the mcdaniel mite, the predominant species on apple. Miticides OW-9, Moricide, and Bayer 36205 were equal to or superior to Kelthane or tetradifon. Bayer 47185 was practically equivalent to the standards. Fair control was obtained with Volck Supreme oil and its effectiveness was not increased by the inclusion of tetradifon. Other materials were ineffective. Bayer 36205 caused some injury to apple foliage. In laboratory screening tests 11 of 59 compounds were worthy of further study.

Field tests in Indiana on apples during the prebloom and early cover spray period showed that a pink-bud application of chlorbenside or two applications of tetradifon, in the first and second cover sprays, were highly efficient--more so than a spray at greentip that contained oil. Tetrasul applied at the pink-bud period was as effective as chlorbenside or tetradifon. Dimite applied at the pink-bud stage was not commercially effective. Indopol polybutene and polypropylene, materials that leave tacky deposits which trap the mites, continued to offer promise for early season mite control but in some tests they caused extensive phytotoxicity. These materials are most promising for use in early postbloom applications. Another sticky substance that shows considerable promise is Foxlene, a by-product of rosin from pine trees. Root zone injections of phorate at the pink-bud period have provided excellent mite control in numerous tests. In other tests residues of phorate were translocated to the leaves but not to the fruit. Similar applications of Di-syston were also effective.

Field comparison of miticides at Vincennes during mid-July showed that it would be advisable for growers to apply two sprays at 7-day intervals, rather than to rely on one application. The more effective miticides for

use in such a schedule included binapacryl, Kelthane, Naugatuck OW-9 and C-417, and Union Carbide 20047. American Cyanamid EI-43064 and dimethoate, while less effective, also gave good control. A number of new compounds were found worthy of further study as the result of laboratory screening tests.

In West Virginia, dimethoate and Zectran were effective summer miticides when used in repeated applications. There was an indication that the number of current cover sprays recommended could be reduced, possibly to five, in most orchards and still give adequate mite and insect control.

The European red mite and two-spotted spider mite were problem pests on both apples and peaches in Ohio. As in Indiana two closely spaced applications of a miticide gave much better control during the summer than a single application. Imidan, Hooker 16-A, and Indopol polybutene H-100 were less effective against the two-spotted spider mite than against the European red mite. A mixture of ethyl-methyl Guthion, Shell 3562, American Cyanamid 43064, Bayer 36205, Animert, GC-3707, phosphamidon and dimethoate gave promising results against both species on apples and/or peaches. Three or more consecutive sprays or heavy dosages of Indopol polybutene H-100 caused leaf yellowing and drop. Bayer 36205 also caused some spotting on Rome and Cortland apples.

In orchard plot studies of concentrated acaricide sprays for control of mcdaniel mite on apple in Washington, good control was obtained with 800 and 400 gallons of spray per acre while poor control was obtained with 200 gallons or less applied with a conventional air blast sprayer and with 60 gallons per acre applied with an air blast concentrated sprayer.

Studies of the translocation of toxicants in deciduous trees at Wenatchee, Wash., made by administrating various compounds in solution through small holes (with brass coupling) in the trunk or large branches, showed that Meta-systox, Dylox, Bidrin, DDT, and dimethoate administered to mature cherry trees, was readily translocated to leaves in various parts of the tree where they caused considerable mortality of the two-spotted spider mites during several weeks. Bidrin killed 89% of the mites one month after introduction into the trees. Dimethoate and Acti-dione translocated in peach trees had a marked effect on the peach silver mite population.

In Poland under P.L. 480 project E21-ENT-5 research efforts to develop a malathion-resistant strain of the two-spotted spider mite by selective treatments were unsuccessful and a search is now underway for naturally occurring resistant strains. This confirms experience in the United States that no case of high resistance in mites has been developed in the laboratory by acaricide pressure applied to a non-resistant colony. Strains of Bryobia praetiosa resistant to organic phosphate insecticides failed to survive low winter temperatures, -39° C., while nonresistant strains survived. Under the low temperature conditions 90% of the European red mite overwintering eggs were killed.

3. Plum Curculio. Parathion, Guthion and dieldrin are the most commonly used insecticides for controlling this insect. Parathion and Guthion are hazardous to handle and dieldrin can be used only in the early part of the season. It is important that the search for safer materials which can be used throughout the season be continued.

In orchard experiments, in Georgia, Bayer 25141 and Bayer 37344 were superior to parathion for protecting peaches from the plum curculio. Imidan, dimethoate and Zectran were less effective than parathion. Bayer 25141 and dimethoate caused foliage injury. In laboratory screening tests against plum curculio adults U. S. Industrial Chemical Co. 781-219B gave excellent initial kill but it had poor residual value. Bayer 44646 was ineffective.

In orchard spraying experiments in Ohio, Bayer 37344, Sumathion, American Cyanamid 43064, and Imidan reduced the number of curculio larvae that emerged from dropped plums by more than 99%. Unsprayed trees produced 537 curculio larvae per tree.

There is an indication that soil in heavily sprayed peach orchards is becoming toxic to plum curculio grubs. In Georgia where 322 of 400 grubs emerged as adults when placed in soil from an unsprayed, uncultivated field only 14 of 400 emerged from soil from an orchard that had been sprayed for a number of years with benzene hexachloride and only 85 of 400 from soil from an orchard similarly sprayed with parathion, except for one application of dieldrin in 1962.

Chlorinated hydrocarbon insecticides applied to the soil at 2 or 4 pounds per acre in Georgia were effective in preventing the development of plum curculio grubs from developing into adults. Tests of such treatments applied in more northern areas indicated that the residues there were less effective. Soil applications of aldrin at 3 to 5 pounds per acre in Indiana and Kentucky and of dieldrin at 6 pounds per acre in New Jersey failed to give satisfactory reductions in adult emergence. In a laboratory test in New Jersey 6 pounds of dieldrin per acre prevented adult emergence, indicating that migration of curculios from outside of the dieldrin-treated test orchard may have been a factor in the poor results obtained.

4. Deciduous Tree Fruit Borers. The peach tree and lesser peach tree borers are considered in some areas to be the most serious pests of peaches and, to a lesser extent, other stone fruits. In a comparative test in Georgia, endrin in a single application to the trunks of peach trees early in July or in two half-strength applications, one early in June and one early in August, gave nearly complete control of the peach tree borer. Similar applications of endosulfan and dieldrin were about equally effective and only moderately less so than endrin. In Indiana a single application of endosulfan to the trunks and scaffold limbs of peach trees at $2\frac{1}{2}$ pounds per 100 gallons of water early in June prevented the development of severe infestations of the lesser peach tree borer and

3 applications to all parts of the trees at 3/4 pound per 100 gallons kept injury by this borer to a low level.

5. Pear Psylla. Increased emphasis has been given to the control of this insect because of its increasing resistance to summer spray treatments and its possible relation to the spread of pear decline in the West.

In experimental plots at Yakima, Wash., three or four summer applications of Guthion gave good control of the psylla but there was evidence of gradually increasing resistance to Guthion. Bayer 36205 was more effective than Guthion but caused some discoloration of pear leaves. Imidan, Zectran, and half-strength Guthion with summer oil gave control equal to that obtained with Guthion at the standard strength of 1½ pounds 25% wettable powder per 100 gallons of water. Guthion 25% wettable powder, 9 pounds per acre applied in 600, 300, 150 and 75 gallons per acre, with an air blast sprayer that delivered 44,000 cubic feet of air per minute, was equally effective in controlling pear psylla regardless of the quantity of solution applied per acre. Results were less satisfactory when Guthion was applied with a sprayer designed for the application of concentrated sprays, which produced about one-fourth the volume of air produced by the conventional sprayer.

Orchard tests of materials applied during the delayed dormant period in Washington showed that the standard oil (1½ gallons)-lime sulfur (3 gallons per 100 gallons of spray) treatment is highly effective for controlling the pear psylla. Morestan (Bayer 36205) gave results equivalent to the oil-lime sulfur spray. Volck Supreme oil 1½ gallons per 100 gallons also gave good results but it was less effective when lime sulfur was included. The effectiveness of an oil spray was not increased by the addition of ethion. Indopol polybutene (H-100) was ineffective.

Pre-pink (cluster bud) sprays of Perthane, Dilan, or Guthion were about equally effective in controlling pear psylla. Indopol polybutene (H-100) was again ineffective. In general, the pre-pink sprays were slightly less effective than delayed dormant sprays.

In laboratory screening tests of 51 materials against pear psylla at Wenatchee, Wash., only Shell SD-8280, General Chemical 4072, Union Carbide 21149, and Bayer 47043 caused greater mortality of pear psylla than Guthion, the standard material. Most of the remaining materials were less effective than the standard.

6. Miscellaneous Insect Pests of Deciduous Tree Fruits. The apple maggot is a serious pest of apples in the northeastern States and northern portion of the Midwest. In Ohio a soil application of endrin at 5 pounds per acre in the spring did not materially reduce the subsequent season's apple maggot fly population or fruit infestation.

Sucking bugs that cause deformed peaches are often responsible for larger losses of peaches than any other insect. There is need for an insecticide that will be highly effective against these insects. In orchard tests in Indiana good control of sucking bugs was obtained with Imidan, carbaryl, Guthion, parathion, Zectran, Bayer 37344 and endosulfan.

The occurrence of TDE-resistant strains of the red-banded leaf roller and lack of agreement on the value of substitute materials for TDE are the basis for a continuing search for more suitable materials for the control of this insect. In field-laboratory and laboratory screening tests in Indiana, 20 new compounds gave good to excellent control of this leaf roller, the most promising of which included carbaryl, Imidan, Zectran, Bayer 37344, Monsanto CP-40294, American Cyanamid EI-43064, Stauffer N-2404 and N-2793, Ciodrin, and Niagara 9203. These materials require further evaluation in more critical tests.

Scale insects continue to increase to an injurious level whenever control measures are relaxed. In tests against a heavy infestation of the San Jose scale on apple in Indiana certain organic phosphate insecticides, particularly parathion, used in several cover sprays gave better scale control than an oil spray alone or when applied with an organic phosphate insecticide at prebloom. Two carbamate insecticides, Bayer 37344 and carbaryl, were especially effective. In Georgia Imidan, diazinon or ethion in two applications late in the summer did not control the white peach scale, a confirmation of the ineffectiveness of summer sprays recorded for the control of this insect in previous experiments.

In Ohio dormant spray applications were ineffective in controlling the blueberry tip borer but two post-bloom applications of malathion or carbaryl or a combination of the two materials gave effective control of this borer as well as of the cherry fruitworm in blueberries.

7. Pecan and Other Nut Insects. Progress continued to be made in studies to develop basic knowledge of the ecology and biology of the more important insect pests of pecans and methods for combatting them. In a field experiment in Georgia EPN alone was as effective in controlling the hickory shuckworm as when used in combination with an adhesive. Two applications of EPN were as effective against a light shuckworm infestation as three applications.

There is need for an insecticide other than a chlorinated hydrocarbon to control the pecan weevil in groves used for pasture. In tests in Georgia, carbaryl, EPN, and Guthion were as effective as DDT against a light infestation of the weevil. Preliminary results of cage tests of soil applications of aldrin, dieldrin and heptachlor at 5 pounds per acre to control the weevil before it emerges were not encouraging.

The occurrence of the pecan leaf casebearer in outbreak numbers in the Southeast the last few years has presented an opportunity to develop improved measures for its control. In Georgia spring applications of Guthion, EPN, or parathion were more effective than those of malathion or Sevin. However, summer applications of insecticides, because of the wider latitude for their timing, have proved to be superior to spring applications.

There is some question concerning the effect of mirids on setting of the developing pistillate bloom in the spring. If the present investigations show that their feeding is responsible for significant crop losses, they may be easily controlled by applications of malathion, parathion, Guthion, or Sevin, as shown by tests in Georgia.

The fall webworm is widespread throughout the pecan producing area. Parathion and Zectran gave nearly complete control of this pest in tests in Georgia and were superior to endosulfan, carbaryl, demeton and malathion as well as to a variety of experimental insecticides.

In an exploratory test in Indiana a malathion-protein hydrolysate bait spray in two applications gave nearly complete control of the walnut husk maggot, a common pest of Persian and black walnuts and butternuts throughout the eastern United States. The result was an average of 75 pounds of nuts per tree instead of a total crop failure as in other recent years.

8. Grape Insects. The grape berry moth, potentially the most serious pest of grapes, was generally not present in injurious numbers during the year. Research conducted on light infestations in Ohio showed that control of grape berry moth was adequate where DDT plus parathion, carbaryl, or Zectran had been used.

Injury to Concord grapes by the grape cane girdler has increased in the Ohio grape belt during the last five seasons. Information on the life history, activity, and pest status of this insect is limited. In Ohio results of spray tests indicated that applications should start during the prebloom period for most effective control. Guthion applied at petal fall and in two subsequent cover sprays gave very good control and was superior to carbaryl. The latter in turn was superior to a combination of malathion with DDT.

C. Insecticide Residue Determinations

1. Deciduous Tree Fruits and Nuts. Residue studies on some of the newer insecticides in Indiana, Ohio, and Washington showed (1) three postbloom applications of 12 ounces binapacryl per 100 gallons of spray to grapes in Ohio left residues of only 0.1 p.p.m. on the grapes 30 days after the final application; (2) in Indiana the magnitude and persistence of residues of tetradifon on apple leaves were increased by the addition of polybutenes; (3) the addition of oil to summer spray mixtures containing carbaryl reduced the initial deposit of carbaryl on apple foliage and fruit

while the addition of polybutene increased the deposit of carbaryl on foliage but not on fruit; (4) Guthion residues on apples at harvest following one to ten applications in Indiana were less than 0.7 p.p.m. 7 days after the final spray; (5) in Indiana harvest residues of Zectran on peaches sprayed with 1 pound Zectran in 7 postbloom applications were 2 and 0.95 p.p.m., respectively, 7 and 14 days after the final application; on apples that received 6 applications of Zectran there was no detectable residue on samples taken 3 to 21 days after the final application; (6) in Indiana lead arsenate residues on apples at harvest were increased by 100% when polybutene was included in the spray mixture before or after the application of lead arsenate; and (7) apples treated with 1 pound Imidan per 100 gallons in 6 cover sprays contained 0.8 and 0.6 p.p.m. of Imidan, respectively, 1 and 14 days after the final application and peaches receiving 7 similar applications contained 0.8 and 0.4 p.p.m, respectively, 15 and 21 days after the final application.

In Indiana soil treated in 1944 with approximately 2300 p.p.m. DDT was sampled in layers to a depth of 25 inches in January 1962. Analyses showed the presence of about 600 to 1000 p.p.m. of DDT remaining.

D. Biological Control

1. Deciduous Fruit and Tree Nuts. Efforts to utilize the DD-136 nematode and associated bacterium to control the codling moth were continued in West Virginia with negative results. While it was again confirmed that the nematode destroys many of the codling moth larvae that cocoon in bands on the tree trunks, the nematode, which is very susceptible to dryness, does not appear able to survive and maintain itself in sufficient numbers in the upper parts of the trees to provide effective control of codling moth larvae.

In Pakistan, under P.L. 480 Project A17-ENT-5, an intensive survey for scale, fruit flies and mites and their natural enemies was carried out in four zones divided in accordance with topography, climate and host picture. The many species collected and reared are now being evaluated to provide a basic list for more intensive study to determine what, if any, beneficial species are worthy of colonization in the United States. Of particular interest was the recording of 19 species of predators of mites, of which 10 were previously unknown in Pakistan. Preliminary indications are that some of these mite predators may be worthy of importation into the United States for colonization. Identification of the many species collected has been a problem but is gradually being accomplished.

In Poland, under P.L. 480 project E21-ENT-2 studies on the biological control of aphids and scale insects and the effects of pesticides on the natural enemies of these pests have provided a list of the injurious and beneficial forms present in the study area and provided the basis for their classification in order of importance. Future studies will be concentrated on the more important injurious species and on the beneficial

forms of greatest possible usefulness. Tar oils and organic phosphate insecticides applied to control the European fruit lecanium scale reduced populations of the scale in the range of 77-82% and those of the two most important scale parasites to about the same extent. In the laboratory five organic phosphorus insecticides were toxic to the predatory lady beetle, Coccinella quinquepunctata, but not all to the same extent, methyl parathion and malathion being the most toxic of those tested. Data on Chrysopa spp., aphid predators, showed that they destroyed from 108 to 521 aphids each during their larval development period. Honeydew was an important part of the diet of these lacewings, influencing markedly their ability to lay eggs.

2. Berry Insects. The spider mites, Tetranychus telarius and T. atlanticus, are serious pests of strawberries in the eastern United States. Insecticides are erratic in effecting their control and apparently have a detrimental effect on their common predators. In a planting sprayed with Kelthane in the fall of 1962 and early spring of 1963, the mite population increased considerably in May then began to decline. Examination of infested leaves May 31 showed a high population of the predatory mite, Amblyseius fallacis, and a low population of T. telarius. The predatory mite had destroyed virtually all the mite eggs as they were laid. An application of malathion shortly after the above examination killed off most of the predators with the result that the population of T. telarius increased and caused foliage injury during June.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Deciduous Fruit and Tree Nut Insects. The sterilization of insect populations by radiation or with chemicals as a means of control or eradication received increased attention during the year. This approach to control offers one possible means of reducing dependence on conventional insecticides. In Washington studies of the effect of gamma irradiation on codling moth stages indicated that eggs are more susceptible to injury from irradiation than pupae. The latter are more susceptible to injury than adults. The irradiation of adults with 30,000 roentgens caused complete sterility of females. Only 1% of the eggs from normal females mated with irradiated males produced normal progeny. When irradiated moths were placed in cages at the rate of 10 treated males, 10 treated females, 1 normal male, and 1 normal female, less than 1% of the eggs deposited produced moths. Moths sprayed with tepa, a chemical sterilant, were also sterilized, indicating a possibility that chemicals may provide a more effective means of sterilization than gamma radiation. None of the eggs hatched when nontreated males and females were mated with moths that had been sprayed with 3 and 5% solutions of tepa. Only 5% of the eggs hatched when nontreated moths were crossed with moths sprayed with a 2.5% solution.

Twenty-two antibiotics tested on the two-spotted spider mite at Wenatchee, Wash., by applying them to greenhouse plants, revealed only three, Pleomycin, Venturicidin, and Hygromycin B, that caused 90% or more mortality.

In Indiana, chemosterilant activity was obtained with apholate against two-spotted spider mites on lima bean plants in laboratory tests at levels between 0.05 and 1.0%, but the 1.0% level was phytotoxic to the bean plants. Allethrin acted as a chemosterilant when used at 16 and 32 ounces per 100 gallons but was also phytotoxic to the bean plants.

In Georgia, tepa, apholate and tretamine showed definite possibilities for use as sterilants of both sexes of plum curculio adults. Mortality was high in all groups of adult curculios injected with or dipped in these materials.

The female moths of certain insects contain a powerful male sex attractant. In Georgia caged virgin female peach tree borer moths or extracts from such moths attracted numbers of male peach tree borer moths. In Indiana similar results were obtained with lesser peach tree borer moths. The next step is to produce or obtain moths in sufficient numbers to provide enough insects or extract of the attractant so that a toxicant-attractant combination can be tested on orchard populations of these borers as a means of direct control through annihilation of males. The chemists also need sufficient material from female moths for identification of the chemical and development of a synthetic product. In Georgia no response was obtained when extracts prepared from male and female pecan leaf casebearers were exposed to orchard populations. Black light traps, however, were attractive to both leaf casebearer and hickory shuckworm adults.

In Ohio a liquid bait composed of a protein hydrolysate and ammonium phosphate was generally superior to ammonium carbonate or a mixture of glycine and sodium hydroxide for attracting the apple maggot, cherry fruit flies, or the walnut husk maggot. In Indiana ammonium carbonate proved to be a practical lure for the walnut husk maggot.

F. Evaluation of Equipment for Insect Detection and Control

1. Pecan Insects. In Louisiana it was again demonstrated that aerial applications of demeton or malathion give good control of the black pecan aphid. An aerial application of benzene hexachloride also gave good control of the pecan phylloxera; however, two applications may be necessary when pecan varieties in an orchard do not foliate at or near the same time. Further tests of aerial applications of insecticides to control the pecan nut casebearer again demonstrated the marginal nature of the effectiveness of this type of application to control this insect. When used in an aerial application, Guthion gave fair control of the nut casebearer and was superior to methyl-ethyl Guthion. Sevin was ineffective.

On the other hand, good control was obtained with a combination of DDT and parathion applied with a standard high pressure sprayer.

2. Grape Insects. In Ohio the speed of operation of the fan on an air-blast concentrate sprayer, applying a 4 X concentration of methoxychlor at 1900 RPM (low speed), 2800 RPM (medium speed), or 3700 RPM (high speed), had no significant effect on the level of residues obtained on grape berries or on control of grape pests. In a vineyard with heavy foliage overhanging open, fixed spar, and overhanging hooded boom grape sprayers were equally efficient in applying DDT sprays as measured by determination of deposits and insect control.

G. Insect Vectors of Diseases

Spread of many important virus diseases is due to the activity of insects and mites. Knowledge of the insect and mite vectors is necessary as a basis for developing methods for preventing spread of the viruses and for determining their host range, season of spread, and other characteristics.

1. Phony Peach Virus. Transmission tests with Oncometopia nigricans, until recently confused with O. orbona, an important proved vector of the phony peach virus, failed to confirm the one previous positive transmission obtained with this species. However, the incubation period of this virus, 2 to 3 years, is so long that confirmation may yet be obtained from tests now underway.

It has been demonstrated in tests conducted in Georgia with the cooperation of the Plant Pest Control Division and Georgia Department of Entomology that populations of the important natural vectors of the phony peach virus can be reduced to a very low level by spraying mixed wooded areas where the vectors hibernate near peach orchards with DDT in two applications about a month apart in the spring. Thus far it has not been possible to correlate reduction of vector populations by this means with a corresponding reduction in the spread of the virus. In a test at Barney, Ga., now concluded, good control of the primary vector, Homalodisca coagulata was demonstrated but phony incidence was disappointingly high. Lack of roguing may have been responsible for the increase in this particular case. In two similar study areas underway near Fort Valley, Ga., vector populations have been reduced to a very low level and thus far spread of the virus has been very limited; however, observations on disease spread in the test orchards over the next two or three years will be necessary to establish the value of this type of control program.

The systemic insecticide Di-syston was very effective in killing phony peach vectors when applied to the soil about young trees at 3 or more grams per tree but damaged the trees severely. Use of Di-syston at 1 gram per tree killed the vectors too slowly to prevent them from effecting virus transmission and also injured the trees regardless of the manner of application. Compound NIA 9205 was less phytotoxic than Di-syston but was

not effective in killing the vectors.

2. Peach Mosaic Virus. For the third consecutive year treatments were applied to all peach plantings, 1643 trees at the outset, in an isolated district in San Bernardino County, California, to determine if peach mosaic virus spread by the eriophyid mite vector, Eriophyes insidiosus, can be prevented. In 1961 and 1962 the treatment was a single spray application at petal fall of 25% diazinon wettable powder at 2 pounds per 100 gallons of spray. In 1963, 1 pound of 50% diazinon wettable powder per 100 gallons was used. It was expected that the spring assay of new cases of disease in 1963 would begin to show effects from the chemical treatments, if any. Indications are that the sprays have been effective since for the first time marked reductions in the numbers of newly infected trees are being recorded.

3. Latent Stone Fruit Virus Complex (ring spot, sour cherry yellow, etc.) All research relating to insect transmission of the latent virus complex in stone fruit trees was concentrated upon the ring spot virus at Corvallis, Oreg. The work there culminated an extensive search for a vector or vectors of stone fruit ring spot virus during which 130,293 individual insects and mites were manipulated. The experiments included 32 species of aphids, 22 leafhoppers, 1 spittlebug, 2 whiteflies, 1 plant bug, 1 beetle, 2 thrips, 3 eriophyid mites and 2 spider mites. Cases of diseased plants occurred in two instances, once in a test of the aphid, Amphorophora rubitoxica,and once in a test of the leafhopper, Euscelidius variegatus. Unusual precautions were taken by the workers conducting the studies to insure against accidental contamination of the plants, leading them to advance the following conclusion: these transmissions are believed to represent infrequent mechanical transfer of the virus by insects; thus these insects are not considered to be vectors of the virus in the usual sense.

From other studies in the cooperative Federal-State project in Oregon, and results of research reported from other locations, the hypothesis of pollen transmission is considered at present to be the most promising explanation of field spread of this virus. Emphasis on this project has been shifted to evaluate this possibility before continuing the intensive search for an arthropod vector. Since the stone fruit ringspot virus occurs in host plants which cannot be cross-pollinated, infrequent insect transfers may be the means of overcoming this barrier to transfer of the virus among different kinds of plants. A field plot has been established to evaluate pollen transmission as a means of field spread of stone fruit ringspot virus.

4. Miscellaneous Stone Fruit Virus Diseases. As reported last year, based on 12 positive cases of transmission, a new species of eriophyid mite from the wild cherry, Prunus emarginata, was determined to be a vector of cherry mottle leaf virus, cause of a disease that is important in sweet cherries in Washington and Oregon. Further work has added four additional

cases, and continuing observations of 300 new experiments should reveal additional successful transmissions. This will complete this phase of the study with this virus.

In Oregon the Federal-State cooperative project encountered an unusual advance by determining a vector of a new, economically threatening virus in sweet cherry, a few weeks after the presence of the virus was confirmed. Pathological studies to date have indicated that the virus is unrelated to stone fruit ringspot virus. The virus has been carried from sweet cherry to peach and also to squash, and from the latter host back to cherry. The aphid, Myzus persicae, transmitted the virus in the initial experiments, and the transmission pattern is now under study. This represents the first instance of a true vector of a stone fruit virus proving to be an aphid.

The peach rosette virus disease continued to increase in Georgia. Thus far results of 181 transmission tests initiated in 1962 with a variety of insects associated with diseased peaches and plums and 54 tests initiated in 1963 have been negative.

5. Pear Decline. The question of whether the pear decline disorder is attributable to toxins injected into the trees by the pear psylla, or to infection by a virus has not been resolved. During the year weight on the side of the virus hypothesis was added by State Experiment Station workers in Washington with issuance of a publication; earlier the theory that pear decline is caused by pear psylla feeding, with no virus involved, was developed from separate research by other Washington State workers.

Federal entomological work on the pear decline problem dealt with experiments intended to reveal possibilities of certain insects and mites functioning as vectors of a causal virus, and experiments to reveal the capabilities of the pear psylla to produce decline through injection of toxin. In the studies of possible virus transmission, the pear psylla became a primary subject of study separate from the evaluations of direct effects of its feeding and introducing toxin. In greenhouse vector tests with the pear psylla, 108 separate experiments were initiated, utilizing insects which had fed upon declining pear trees. Ten species of leafhoppers which inhabit pear orchards were similarly used in a series of 106 experiments. Test trees were in their first year of growth. Interesting tree reactions are being recorded in certain series, but these may be temporary and unrelated to true pear decline; insufficient time has elapsed (one year and less) to justify as yet an evaluation of results.

Another approach involves use of larger healthy test pear trees planted in the soil inside screen cages large enough to permit growth for 5 to 6 years, when kept pruned to a 6-foot height. Such trees are approximately the same size as those observed in the field to react typically when entering a decline condition. Five cages were erected, each enclosing 21 trees; one group is maintained free from insects; one group receives pear

psylla from diseased field trees; one group receives pear psylla from field trees in a decline-free area; one group receives pear psylla reared on healthy trees; one group receives buds and grafts from diseased trees. This experiment was initiated in the spring of 1963, and by all precedent should reveal some results after one to two years.

The trees in the 172 vector tests reported last year with a new species of eriophyid mite occurring on pear are being observed. All tree reactions need to be observed for a longer period to permit accurate assay of results.

Surveys for pear psylla infestations and pear decline disorder in California did not reveal any significant extensions of the ranges of either. The San Diego County pear psylla infestation remains the only Southern California record.

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AREA NO. 4. CITRUS AND SUBTROPICAL FRUIT INSECTS

Problem. Efficient production of citrus and subtropical fruits depends upon the availability of effective measures for combatting the many insects and mites that attack these crops. There is a constant need for research to improve present control methods and to secure the necessary information to provide a sound biological basis for their effective development and application. Additional research is needed on biological control agents, including parasites, predators, and diseases; on the integration of biological and chemical control measures; and on safer, more effective, and more economical insecticides to minimize or avoid objectionable residues and hazards to fish and wildlife. Attractants, chemosterilants and other growth-affecting materials and the sterile-male technique are among new or revised approaches to control that need to be investigated. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires research to insure the availability of effective, low-cost detection methods, insect control treatments that can be used to permit movement of commodities under plant quarantine regulations, and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

USDA PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. The program is carried on at Beltsville, Md., Honolulu, Hilo, and Kahului, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Brownsville and Weslaco, Tex., in cooperation with entomologists, chemists and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research Division; at Hoboken, N. J., in cooperation with the Plant Quarantine Division; at Mexico City, Mexico, in cooperation with the Defensa Agricola of the Mexican Secretaria de Agricultura; on the islands of Guam and Rota in cooperation with the U. S. Navy and Trust Territory of the Pacific Islands.

The Federal scientific effort devoted to research in this area totals 31.5 professional man-years. Of this number 5.8 is devoted to basic biology, physiology and nutrition; 3.6 to insecticidal control; 1.0 to insecticide residue determinations; 3.4 to biological control; 9.7 to insect sterility, attractants and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.6 to varietal evaluation of insect resistance; 1.1 to insect vectors of diseases; and 1.3 to program leadership.

Additional research (4 professional man-years) is in progress under a grant of P.L. 480 funds to the Plant Protection Department of the Arab

Republic, Dokki, Egypt, for studies of induced sterility in males of the Mediterranean fruit fly, Ceratitis capitata, as a means of controlling and eradicating this pest. In addition, a portion of a grant of P.L. 480 funds (10 professional man-years) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan, is applicable to insects affecting citrus fruits and to tropical and subtropical fruit fly problems in the United States.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Citrus Insects and Mites. Surveys revealed the presence of a rust mite, Aculus pelekassi, first found in the United States in 1961 at Orlando, Fla., in citrus nurseries and groves in 13 counties of Florida. The species feeds on fruit and immature citrus leaves, causing distortion of leaf tissue and brown spots on the lower leaf surface. High populations have been maintained on Murcott honey orange seedlings for ten months in an air-conditioned greenhouse; in groves it does not appear to be able to compete on equal terms with the citrus rust mite (Phyllocoptruta oleivora).

Techniques for mass rearing rust mites on citrus in Florida have been developed to a point where adequate numbers are continuously available for evaluating sterilants, antimetabolites, and other chemicals of potential biological activity. Mites are reared on Murcott honey orange or Pineapple orange seedlings in greenhouses maintained between 75 and 85° F. and 50 and 75% R. H. Aculus pelekassi survives conditions of low humidity better than P. oleivora; humidities below 30% inhibited reproduction of the citrus rust mite.

Exploratory work at Riverside, Calif., on the possibility of propagating the citrus red mite on an artificial medium revealed that the mites would feed through certain moisture-proof membranes or gelatinous substrates, such as collodion, cleaners plastic, Du Pont 100 polyethylene and Du Pont 195 MSD-54 cellophane, coated with nitrocellulose; however, it will be necessary to develop a suitable method of confining the mites to the membrane before intensive studies of nutritional requirements for extended rearing can be made.

Little information is available as to the rate of movement and other dispersal habits of the citrus red mite on citrus trees. Isolation and production of an albino strain of this mite provided a tool for obtaining such information. In a preliminary experiment conducted in California in November, movement was slow and restricted. Following release of several hundred of the albino mites on a Valencia orange tree, the mites had moved after 1 and 4 weeks only 6 and 24 inches, respectively, from the original point of introduction. It is expected that the rate of dispersal might be greater in warmer weather.

Periodical surveys of 30 citrus groves in the Rio Grande Valley, Texas, revealed that brown soft scale infestations remained generally light throughout 1962 and until a veritable explosion of the scale population occurred in May 1963. Concurrently there was a decided drop in parasitization of the scale. This coincided with the cotton treatment program but it has not yet been determined definitely that drift of insecticides to the citrus orchards was the cause of the scale outbreak.

In Florida the life histories of Micromus posticus and M. subanticus, important predators of citrus aphids, were similar under laboratory conditions. They required 15 to 16 days for larvae to become adults.

2. Subtropical Fruit Flies. In Hawaii, further developments of mass-rearing techniques for tropical fruit flies have reduced the labor required for handling mature larvae and pupae. A cement mixer blends vermiculite with mature larvae and a mechanical sifter is later used to separate the vermiculite from the pupae. Nine million Mediterranean fruit flies, 26 million oriental fruit flies, and 336 million melon flies were produced this past season. Most of the melon flies were used in a sterile male release eradication test on an island in the Western Pacific.

In Hawaii, populations of the oriental fruit fly, Mediterranean fruit fly and melon fly remained at about the same levels as in last 5 years. In the Mariana Islands, wet and dry seasons cause monthly populations of the oriental fruit fly and melon fly to fluctuate by as much as 70 times with sharp increases during the rainy seasons.

Under caged conditions 100 virgin females of the melon fly confined with a single male produced about 1/6 as many hatchable eggs as the same number with 100 males. Normal females punctured 82% of the cucumbers placed in cages and produced larval infestations in 63%. In a comparable test with an equal number of sterile females, only 40% of the cucumbers were punctured. Under field conditions, wild melon flies laid eggs in 44% of 354 punctures they made in 129 cucumbers, indicating that not all stinging is accompanied by egg deposition.

In laboratory studies with 3-day-old medfly females in copula with males of the same age immotile sperm were present in the spermathecae of 11 of 12 dissected. Four of the flies contained motile sperm in the tubes. Of 25 females from the same lot not observed in copula, 5 had mated. Only 1 of the 37 medflies contained any eggs approaching maturity. These data indicate that the male medfly can reach sexual maturity in 3 days.

Dissections in Hawaii of 20 medfly females caught by trimedlure in Florida showed that the females had fully developed eggs in them but they contained no sperm. A similar response of the sexually mature females to the synthetic male lure in the absence of wild males has been noticed for females of the oriental fruit fly and the melon fly. When catches in male lure traps are predominately female, the male population is extremely low.

In Mexico, tepa-sterilized males competing with irradiated males (5 kr) for a single virgin female were the more aggressive. The number of matings by the tepa-sterilized males exceeded those of irradiated males by a ratio of about 3 to 2. There was no difference in the number of matings between tepa-sterilized males and untreated males. These tests were conducted in the laboratory over a 6-week period and the males were replaced every 3 to 4 days. Recaptured tepa-sterilized males were similar to captured native males in mating aggressiveness.

An effective technique has been developed for the identification of recaptured Mexican fruit flies. Flies that emerge in vermiculite containing a fluorescent dye-petrolatum-stearic acid mixture are marked on the ptillinum and other parts of the body. Dyed flies are easily detected under ultraviolet light after being immersed in fermenting or protein-borax lures for 10 days.

B. Insecticidal Control

1. Citrus Insects and Mites. In laboratory studies at Orlando, Fla., undertaken to determine some of the factors influencing the effectiveness of acaricides for control of the citrus rust mite, 4- to 5-day-old adult mites were more susceptible to zineb than younger mites. Ethion gave higher mortality on mature than on immature leaves of Murcott honey orange seedlings and was more effective in controlling citrus rust mites on Key lime, sour orange, and Columbia sweet lemon seedlings than on Temple, Jaffa, and Florida sweet orange seedlings. In most tests, mortality of the mites was higher on the upper surface of leaves than on the lower surface.

In the Orlando laboratory 10 p.p.m. of zineb gave complete mortality of citrus rust mites during the summer of 1962, but by early fall there was a marked decline in the mortality resulting from a comparable amount. In recent experiments 50 or 100 p.p.m. of zineb have given less than 50% mortality of mites. Experiments with various formulations of zineb using different sources of water and acetone, different populations of mites (from laboratory colonies and from field collections), and variations in humidity, light, or temperature have been unsuccessful in determining the reason for these changes in effectiveness of zineb against citrus rust mites in the laboratory.

In replicated single-tree field plots at Orlando, Fla., zineb has given good control of citrus rust mites when applied at 1 lb. of 75% WP per 100 gallons of water, but only fair control when used at 1/2 lb. per 100 gallons.

In a comparative test on oranges in Florida Indopol H-100 and Niagara 9102 gave fair control of citrus rust mites for about 9 weeks, while Chemagro 36205, Stauffer R-1504, Kelthane, and binapacryl (NIA 9044) gave control for only 3-6 weeks. Texas citrus mite populations were controlled by R-1504, Indopol H-100, and Kelthane. Plots treated with NIA-9102 had

higher populations of Texas citrus mites than were found on untreated trees. Fruit on trees sprayed with Indopol H-100 had dark green splotches for 4 months after treatment. In another test on oranges zineb and Dithane M-45 were about equally effective against the citrus rust mite and superior to DuPont 328, Shell 3562 and 7438, Nabac 25, and NIA-9203. In still another replicated field test, Stauffer R-1504 was as effective as ethion plus oil and slightly more effective than zineb, ethion, or chlorobenzilate in control of the citrus rust mite; also, zineb and ethion were superior to Bayer 36205, NIA-9102, and Hooker 16A. Stauffer R-1504 and ethion alone or with oil gave almost complete control of the Texas citrus mite. Trees treated with zineb, Hooker 16A, NIA-9102, or chlorobenzilate had higher Texas citrus mite populations than untreated trees.

Because of resistance to the new acaricides, the citrus red mite continues to be the most important pest of citrus in California. Strains of mites resistant to demeton and ovex have been reared in the laboratory without further exposure to chemicals since 1958. After 60 generations, the resistance of the demeton strain appeared to be leveling off at about 35 times the tolerance of a susceptible strain and the ovex-resistant strain at about 60 times. Following an accidental exposure to carbophenothion, the resistance index of each strain increased to 117 and 123 times, respectively. After 28 and 19 additional generations, the indexes of the two strains decreased to 23 and 91 times, respectively. These studies indicated that a significant degree of resistance to certain chemicals may be retained for many generations and that a high degree of resistance may be regained rapidly upon further exposure to chemicals.

In laboratory screening of new chemicals against California red scale, Bayer 45,432 and American Cyanamid CL 43,064 continued to compare favorably with parathion and were considered worthy of field evaluation. In preliminary laboratory tests, Monsanto CP 40,273 and Bayer 45,556 also compared favorably with parathion.

California red scales sprayed with Shell SD 3562 were characterized by abnormal cover development in the immature stages and shedding of covers from many of the mature stages. Counts made two months after the spray application showed 43% of the scales on the fruit and 18% on the wood with covers missing or abnormal. The number of such scales in adjacent parathion plots was negligible. SD 3562 was more effective than parathion against scales on the fruit and was about equal against those on the wood. As in an earlier tree-reaction experiment, there was no plant injury from these sprays.

Laboratory studies were conducted from 1958 to 1962 to determine whether resistance to parathion could be induced in California red scale by selection pressure. Of 30 generations reared, 20 were sprayed with LD 50 dosages of parathion and the strain perpetuated from survivors. A slight rise in tolerance occurred following the early sprays, but there was no further increase. This indicates that the gene for resistance to parathion

is absent or rare in this species. No evidence of red scale resistance has been detected in citrus groves sprayed with parathion for 10 to 12 years.

Dimethoate, 1 pint per 100 gallons, damaged leaves of small citrus trees in a greenhouse as well as those of several varieties of orange, lemon and lime seedlings. In the field in Florida, at both 1/2 and 1 pint per 100 gallons, this material burned new growth in the spring and caused leaf and fruit droppage from sour orange and some rough lemon varieties of citrus trees and failed to control snow scale. Good control of snow scale was obtained with ethion plus oil.

C. Insecticide Residue Determinations

1. Subtropical Fruit Flies. At Honolulu, Hawaii, ethylene dibromide and ethylene chlorobromide residues were determined in packaged sweet peppers of Yolo Wonder or California Wonder varieties to supplement mortality data obtained with these fumigants. Similar determinations were made for papayas, oranges and other tropical fruits and vegetables.

2. Analytical Equipment. At Hoboken, N. J., the Davis halide meter gave rapid analyses during fumigation of up to 7 oz. of ethylene dibromide per 1000 cu. ft. and to 14 oz. or more with use of a sample dilution technique. In further studies, the thermal conductivity apparatus (Fumescope) is proving to be as useful with ethylene oxide-freon mixtures, as it is with carboxide. A method was developed for doubling the range of the T/C apparatus for determining amounts of carboxide or methyl bromide in high dosage fumigations. This technique utilizes a "Y" with identical sampling tubes of equal length with one tube opening to the open air to give 1-1 sampling dilution. Chemical gas detector tubes (Kitagawa, of Japanese manufacture) appeared excellent for use on low concentrations, including those near the safety threshold of methyl bromide. A similar type tube (Mine Safety Appliance Co.) also appeared promising for either methyl bromide or ethylene dibromide. The Kitagawa detector tubes can be used in areas where the use of flame-type detectors would be hazardous.

D. Biological Control

1. Citrus Insects and Mites. Determination of the role of parasites, predators, and diseases in the control of citrus insects and mites and studies to improve their usefulness by the introduction of additional beneficial species or through development of integrated control programs are major activities of the research being conducted at Lake Alfred, Fla., in cooperation with the Florida Experiment Station, and at Orlando, Fla. In a 4-year comparison, sulfur spray and dust programs promoted heavier scale populations than programs of zineb alone or with oil. Zineb gave inadequate control of citrus rust mite but with oil added provided good scale and spider mite control. Populations of Agistemus spp., a common predator, were affected severely by sulfur applications but not by zineb

alone or with oil. In periodic surveys of 27 Florida groves through the fall of 1962, 9 of which were unsprayed, 9 treated with sulfur and 9 treated with materials other than sulfur, the heaviest scale populations were found in sulfur-treated groves. Parasites were active in sulfur-treated groves but not enough so to prevent increases in scale infestations.

Introduction of the mite predator Ablydromella rickeri into Florida from California resulted in 1 recovery from 14 releases in 1962 and in 4 recoveries from 5 releases made in 1963. This species feeds and reproduces well on the citrus rust mite. At the same time predators of eriophyid mites are being tested on other hosts than citrus against the citrus rust mite. Unfortunately, Typhlodromus pyri, which feeds on the apple rust mite in Canada, and Typhlodromella rhenana, collected from broad-leafed shrubs in California, have not been able to maintain themselves on citrus rust mites.

The primary purple scale parasite (Aphytis lepidosaphes) and Florida red scale parasite (Aphytis holoxanthus) successfully survived the freeze of 1962. A. holoxanthus, introduced in 1960, appears to be replacing Pseudhomalopoda prima as the dominant red scale parasite in Florida. Chaff scale parasites appeared to be severely affected by the freeze and heavier than normal populations of the chaff scale are expected to develop.

There has long been some doubt concerning the value of Manatee snails as predators of scale insects and mites in Florida. In the course of studies initiated in 1960 and concluded in 1963, no significant differences were noted in scale insect or mite populations on trees with and without snails.

In Florida, zineb reduced the effectiveness of natural control of Texas citrus mites in tests in 3 orange groves. Populations of Texas citrus mites decreased on untreated trees during the three-week period following treatment, whereas there was either only a slight decline or an increase in population on trees sprayed with zineb. Similar results were obtained using NIA-9102 and DuPont 328.

Studies of a viruslike disease of the citrus red mite continued to occupy the major portion of the work program in California. Results of field plot experiments in which the pathogen has been applied to control this mite are still inconclusive. Special studies suggest that higher infection rates of the disease results from the introduction of still active diseased mites than when the pathogen is applied in a spray and when mite populations are high than when they are low. Characteristic birefringent crystals associated with diseased mites occurred in only about 1% of the field mites sampled from known diseased populations when the mites were mounted immediately for examination. This low initial frequency of crystals renders observations for their presence of little value as a method for rapidly detecting the disease in field surveys. When the mites were cultured before examination, however, a significant increase in the number

of mites showing crystals occurred after 4 days, or about 1 or more days before symptoms were readily apparent. The disease crystals are highly variable in their stability. In some amounts made in Hoyer's medium, crystals disappeared entirely within 5 months; in others there has been little apparent change in over 2 years.

Bioassays to determine the effect of insecticide drift from cotton fields into citrus groves in Texas failed to show differences in scale and parasite populations following 8 airplane applications to cotton at 4 to 5 day intervals of methyl parathion at 0.5 pound per acre prior to June 12 and methyl parathion plus DDT and endrin in subsequent applications. However, drift into citrus groves results from such applications, the extent varying with air conditions and method of application. In 1962 air samples showed the presence of as much as 112 µg of methyl parathion/m^3 air over a 2-hour sampling period starting 1 hour after the end of spraying. High volume air samples showed 0.003 µg/m^3 2 to 3 hours after spraying. Drift residues of 5 µg/sq. ft. were recorded at distances up to 1056 feet from cotton, at a wind speed of 12 m.p.h. Data from 1963 tests are not complete but spray residues have been recorded at distances up to 1300 feet downwind from sprayed cotton.

Introductions and releases were made in Texas of 5 parasite species from Israel and 1 from California against the brown soft scale. None of these have become established, possibly because of unfavorable conditions during time of release.

In Pakistan, under P.L. 480 Project A17-ENT-5, an intensive survey for scales, fruit flies and mites and their natural enemies was carried out in four zones divided in accordance with topography, climate and host plants. The many species collected and reared are now being evaluated to provide a basic list for more intensive study to determine what, if any, beneficial species are worthy of colonization in the United States. Of particular interest is the recording of 19 species of predators of mites, 10 of which were previously unknown in Pakistan. Some of these predators may be worthy of importation for colonization in the United States. Identification of many of the species collected has been a problem but is gradually being accomplished. There is also under study seasonal fluctuations of the subtropical fruit flies Dacus dorsalis, D. zonatus, and D. cucurbitae and climatic factors affecting their distribution.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Fruit Flies. The first successful use of the male annihilation method has eradicated the entire oriental fruit fly population in a pilot test on the Pacific Island of Rota. This island, 33 square miles in area, is located 37 miles north of Guam. It was an ideal test site because of its isolation. A strong attractant was used to lure the males to an insecticide that killed them. After all males had been annihilated, reproduction stopped and the species disappeared from the island. The attractant used

was methyl eugenol, which the males eat avidly; the insecticide mixed with it was naled. Two methods were used to distribute the poisoned lure on Rota. Over most of the island cane-fiber board squares saturated with methyl eugenol containing naled were distributed by Navy aircraft. The cane-fiber board pieces were about two and one-fourth inches square by three-eighths of an inch thick. Village areas were treated by suspending from trees 6 and 8-inch pieces of cane-fiber containing the lure-poison mixture. At the beginning of the experiment, the cane-fiber squares were dropped at 3-week intervals and later reduced to 2-week intervals. Fifteen drops were completed from Nov. 1, 1962, to June 25, 1963. The rate of distribution was 125 squares per square mile. The permanent bait stations in village areas were treated once a month with fresh poisoned-lure mixture.

The effect of the treatment on the male oriental fruit flies was spectacular. Traps baited with methyl eugenol to determine the male population indicated an average of 262 male flies for the 2 weeks before treatment started. The first drop reduced catches by 93%. What was left of the male population was drastically reduced after each of the succeeding four drops. Catches indicated a reduction of 99.566% of the male population by the end of one generation or after a period of 5 weeks. After three generations and five drops, reduction in the male population was 99.9996%. Bait trap catches indicated 100% reduction by the tenth drop. The last bait catch of an oriental fruit fly was in mid-April, about $5\frac{1}{2}$ months and four generations after the start of the experiment.

In another outstandingly successful experiment in area suppression of a population of a serious pest, eradication of the melon fly was achieved on Rota with an integrated chemical control and radiation sterilization program that caused the insect to bring about its own destruction. In this large scale experiment, carried out with the cooperation of the U. S. Navy and the Trust Territory of the Pacific Islands, 4 to 10 million melon flies previously made sterile by exposure to gamma rays were released each week beginning in September 1962 and ending July 4, 1963. A total of 180 million flies were produced in Hawaii and flown to Guam for processing and distribution on Rota. When sterile males--either dropped from aircraft or released from cages on the ground--mated with native flies, the resulting eggs did not hatch, thus reducing the new generation. The repeated and systematic release of sterile males eventually wiped out the flies. Within three weeks the sterile flies "overflooded" the native fly population by a ratio of more than 13 to 1. By early December, overflooding was 50 to 1 and it reached at least 100 to 1 by early January. No melon fly maggots have been recovered from watermelons, cantaloups, pumpkins, cucumbers, or tomatoes since December 26, 1962. Average infestation in the first four months of 1960, 1961, and 1962 ranged from 4.5 larvae per pound in tomatoes to 30 in immature cantaloups. Malathion-protein hydrolyzate bait was used to reduce the numbers of wild melon flies on the most heavily infested farms to a point where strong widespread overflooding with sterile flies could be achieved almost immediately. This effective

integration of biological and chemical control methods shortened the time required to obtain eradication and reduced the cost.

A small-scale area control test conducted in 1963 in a mango grove in northeastern Morelos in Mexico, utilizing 28 bait-chemosterilant feeding stations, also gave outstanding results suggesting a possible new technique for the control of the Mexican fruit fly. These stations were baited with 1% enzymatic hydrolysate of cottonseed and the design of the trap was such that attracted flies were forced to come in contact with a wick moistened with water containing green dye and 0.025% tepa, the latter an effective chemosterilant. Flies taken in glass traps showed that about 50% of those in the small isolated test orchard had visited these feeding stations as indicated by the green dye the flies consumed. The ratio of gravid to non-gravid females captured in the test grove was less than one-third of that in a control grove. Fruit samples picked weekly showed no infestation in the test grove in April compared to 3% infestation in the control grove. Fruit from the test grove remained remarkably free of fruit fly infestation (less than one-half percent infested) throughout May; whereas, more than 60% of the fruit samples from the control grove became infested.

The effectiveness of overflooding wild populations of Mexican fruit flies with tepa-sterilized flies was demonstrated again in 1963 in a 10-acre mango grove at El Bebedero, Morelos, Mexico. The first test was made in 1962. About 9 million flies were released in this grove from stations containing puparia that had been treated with a 5% tepa solution. Less than 1% of the fruit harvested through May 21 was infested, whereas 76% of the fruit was infested in check groves a mile or so from the release stations. The flies were sterilized by dipping pupae in a tepa dip. Sterilization was accomplished when the adults became contaminated by tepa residues as they emerged.

In Hawaii, laboratory tests to develop methods of sterilizing fruit flies with chemosterilants also indicated that a tepa solution dip of pupae will be effective for the Hawaiian fruit flies. Emerging melon flies forced to pass between sponges containing 0.5% apholate did not produce eggs; a 1.5% solution gave similar results on the oriental fruit fly. For both species less chemosterilant was needed to cause sterility in the males than in females. Residues of 1:10 apholate or tepa-protein hydrolysate (food attractant) in water spray on foliage was very effective against all three species.

Trimedlure-baited wicks exposed for 9 weeks in December and January in Florida were still as attractive to medfly as freshly-baited wicks when tested in Hawaii. Studies of evaporation rates of trimedlure in Florida showed that effective amounts can be maintained on 3/8" wicks by retreating at intervals of 3 to 4 weeks during the summer and 6 to 9 weeks during the winter and on 3/4" wicks by retreating at intervals of 6 to 9 weeks during the summer and 9 to 12 weeks or longer in the winter.

In Egypt, under P.L. 480 Project F4-ENT-3, research preliminary to field tests of the release of sterile males of the Mediterranean fruit fly to control or eradicate this insect is well underway. The technique for mass-rearing the medfly under Egyptian conditions to provide the numbers of flies needed for such an experiment is receiving major attention. Contamination of the rearing medium with a phorid fly has proved to be an unsuspected problem that must be solved. Meanwhile, a test site has been located and studies to assess the fruit fly population throughout the year are in progress.

F. Evaluation of Equipment for Insect Detection and Control

In tests conducted in Hawaii, a trap containing solid trimedlure (57° C. MP isomer) provided performance equal to the standard. With modification of the lure holder to facilitate removal of the trapped insects, this method may prove useful in Mediterranean fruit fly detection programs.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. The new 24 oz. ethylene dibromide per 1000 cu. ft. fumigation at 50-60° F. was used at Hoboken, N. J., for 120 fumigations of approximately 85,000 cases of Israeli (Jaffa) oranges in large, steel chambers, using axial fan recirculation near two changes per minute. Gas concentrations, distribution, and penetration into fruit boxes with different types of stacking were satisfactory in a series of over 225 analyses, as were the stainless-steel electric stoves used for vaporization of gas. Gas concentrations were far below the maximum acceptable concentration of 25 p.p.m. for personnel safety in warehouses used for holding fumigated fruit. Tolerance of Jaffa oranges to the heavy dosage was satisfactory.

Further tests have been conducted to develop fumigation schedules for infestation of fruit flies in packaged sweet peppers. Ethylene dibromide treatments were phytotoxic at effective levels whereas ethylene chlorobromide caused less injury. Mediterranean fruit fly infestations in packaged oranges required the same dosage of EDB at 60° F. as at 50° F.

2. Deciduous Fruit Insects. Specifications for minimum methyl bromide concentrations were developed at Hoboken, N. J., for use by the Plant Quarantine Division in tarpaulin or van fumigation of Chilean fruit (plums, grapes, apples, etc.). These permit immediate correction for under-dosage or leakage loss. The tolerance of Chilean plums (Santa Rosa variety) was satisfactory at recommended schedules of 4 lb. of methyl bromide for 2 hours at 40-49° F., and 6 lb. for 2 hours caused injury.

Tests in New Jersey indicated that complete control of curculio can be obtained in blueberries with 2 lb. of methyl bromide per 1000 cu. ft. or 1½ lb. in combination with 1/2 lb. of ethylene dibromide. Maggot infestation in apples or blueberries was again controlled with low

concentrations of methyl bromide or ethylene dibromide. Prepupae apple maggots four or more days old were highly resistant to fumigation, some surviving treatment with methyl bromide at 2 lb. for 4½ hr. near 71° or 5 hr. near 51°, or a combination of 1½ lb. of methyl bromide and ½ lb. of ethylene dibromide for 4 and 5 hr., respectively. These schedules are above the tolerance limits for apples and some other fruit. There was no difference in the resistance of pupae developing in apples or blueberries.

3. Miscellaneous Crops. Minimum methyl bromide schedules were developed at Hoboken, N. J., for tarpaulin and/or railway car fumigation at various temperatures of broomcorn infested with durra stem borer, Sesamia cretica, European corn borer and other pests. Both Italian and Argentine broomcorn sorbed very large amounts of methyl bromide at 42-75° F., particularly in the first four hours of fumigation. Sorption was much less thereafter. Minimum concentrations were developed for maximum loads. These varied from 31-41% of the dosage to the fourth hour of fumigation and 22-31% for the rest of the 24 hr. exposure at 40-60° or above. When more methyl bromide had to be added during fumigation, sorption losses were less than for the initial dosage.

Faba beans (Vicia faba), imported mainly for food, had excellent tolerance to methyl bromide varying from 3 lb. for 7 hr. at 42° F. up to 3 lb. for 3 hr. at 96° or to excessive schedules with a 1 lb. overdose or a double fumigation at a 3-month interval. No effect was noted on germination or taste in preliminary tests. Imported garlic bulbs showed good tolerance and no detrimental taste effect, even when double the standard schedule of methyl bromide under 15 in. vac. was used for garlic weevil and other quarantinable insects.

4. Snails. Further work was done at Hoboken, N. J., on quarantine treatments for estivated Cochlicella, Theba, and other snails intercepted on military and other cargo from Mediterranean areas. Some snails survived over 12, and a few for 18 months, under severe conditions of very dry, cool, or warm storage, without food or water. All were dead after 21 months. A mixture of ethylene oxide 10%-carbon dioxide 90% (Carboxide) gave further promising results in large-scale tarpaulin fumigation trials near 55° F. Gas vaporization appeared satisfactory simply by direct discharge from the gas cylinder placed underneath the thin polyethylene tarpaulin. Procedures for the fast application of this fumigant and for checking concentrations and/or leakage in tarpaulin fumigation were determined. Carboxide may be used safely on household goods, electronic equipment and other cargo that methyl bromide (the standard fumigant) might injure. Specifications for Carboxide fumigation were prepared for the Plant Quarantine Division and have since been adopted in their treatment manual for regular use on snail-infested cargo.

5. Ionizing Radiation. In Hawaii the investigation of ionizing radiation for commodity treatments has been continued. No injury was noted when gamma radiation was applied to sweet peppers at 150 kr, eggplant at 50 kr, pineapples at 100 kr, and Haden mango at 200 kr. Adult mango weevils in Haden mango seeds survived 9.15 kr. However, larvae and pupae failed to survive 10 and 50 kr, respectively. Sexually mature and immature weevils were sterilized by 5 kr and 15 kr, respectively.

H. Insect Vectors of Diseases

1. Citrus. At Orlando, Florida, continued emphasis was placed on studies to determine factors that influence spread of the tristeza virus by aphids. Low transmission efficiency has made it difficult to obtain enough data for definitive conclusions. Experiments thus far have failed to substantiate indicated differences between vector efficiency related to sources of virus inoculum. There is increasing evidence that aphids from different sources or strains may vary in their efficiency as vectors. In tests of various possible controlling factors the size of Key lime indicator plants did not influence the rate of transmission. The rate was higher when test plants were held in a screenhouse than when they were held in an air-conditioned greenhouse. The number of aphids used also influenced the rate of transmission. Ten, 25, 50, 100, and 200 melon aphids transmitted tristeza to 5.8, 3.3, 8.4, 10.0, and 14.6% of Key lime indicator plants, respectively. Experimental transmissions have increased appreciably since melon aphids for virus transmission studies have been reared under controlled temperature and humidity conditions.

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AREA NO. 5. FORAGE AND RANGE INSECTS

Problem: Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus, and stink bugs, the alfalfa weevil, root borers, spittlebugs, and a variety of aphids including the spotted alfalfa aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of nonchemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., Mesa, Ariz., and Columbia, Mo., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Florala, Ala. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Work on white grubs at Lincoln, Nebr., is cooperative with the Nebraska Experiment Station. Research on clover and grass insects at Forest Grove, Oreg., is conducted in cooperation with the Oregon

Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Studies on varietal resistance, insect vectors of plant diseases and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops) and S-55 (Alfalfa Insects).

The Federal scientific effort devoted to research in this area totals 26.9 professional man-years. Of this number 4.0 man-years are devoted to basic biology, physiology, and nutrition, 5.0 to insecticidal and cultural control, 5.3 to insecticide residue determinations, 3.9 to biological control, 0.8 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 5.3 to varietal evaluation for insect resistance, 1.0 to insect vectors of diseases, and 1.1 to program leadership.

A P. L. 480 project, (E21-ENT-9), "Insect Vectors of Virus Diseases of Various Forage Legumes" is underway with the Research Institute of Plant Protection, Poznan, Poland.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Grasshoppers. Extended drought and scarcity of succulent vegetation in Arizona from mid-spring to the end of 1962 were unfavorable to the desert grasshopper, Trimerotropis pallidipennis pallidipennis. The second generation that usually develops in late summer or early fall did not occur in 1962. Hatching of the first generation was irregular and extended from February to early April. Nymphal growth was retarded by unusually moist cold weather. Adults first appeared in early April and by mid-May all specimens observed were adults. There was very little egg development in adult females until early October. No nymphs and extremely few adults of the 1962 hatch were observed during the winter of 1962-63. Hatching of the first 1963 generation began about February 15 and progressed rather uniformly through early March. Some nymphs had reached the fourth instar by March 11-12. In April 1963, the average population was 0.07 per square yard compared with 0.20 in 1962. The decline was caused mainly by dry conditions in nonirrigated land where there was no second generation in 1962.

In alfalfa fields in south-central Arizona the average grasshopper population in April 1962 was 0.42 per square yard compared with 0.17 per square yard in 1961. The migratory grasshopper, Melanoplus sanguinipes, was dominant. The average summer population of this species during July and August 1962, was 0.25 per square yard as compared with 0.17 in 1961. The migratory, desert, and differential grasshoppers were the leading species in the summer survey. In April 1963 the average population was 0.28 per square yard, a noticeable reduction from that in April, 1962. The migratory grasshopper comprised 94% of the grasshoppers collected.

In late June 1962 heavy populations up to 45 per square yard were found in range meadows, alfalfa, and small grain fields in high-elevation areas in eastern Arizona. Plant damage ranged from 25 to 50%. Important grasshopper species were Camnula pellucida, Melanoplus bivittatus, and M. femur-rubrum. No internal parasites were found in samples of adults examined during 1962.

Grasshopper populations in four range plant habitats at Peeples Valley, Ariz., averaged 0.77 and 0.61 per square yard in June and July 1962, respectively, compared with 4.0 and 1.91 in 1961. The decrease was coincident with severe drought and very poor and closely grazed vegetation in the spring and much of the summer of 1961. Populations differed very little in forbs, mixed grass and forbs, grass, and Juncus meadows.

On range-recovery plots in Arizona, the average square-yard grasshopper numbers on a sparse grass area for April-July 1962, in fenced and grazed untreated plots were 1.9 and 1.8, respectively. Green plant conditions favored greater grasshopper development than in 1961. By mid-July the percentage of blades eaten by one grasshopper per square yard in the fenced plot was 18.0, as compared with 12.3 in 1961. Leading species were Aulocara elliotti and Hadrotettix trifasciatus. In a good grass area with good management practices, the average grasshopper populations in fenced and grazed check plots were 1.7 and 3.3 per square yard, respectively. In mid-August a peak number of 8 grasshoppers per square yard occurred in the grazed area, owing to a good hatch of summer species and second-generation Melanoplus sanguinipes. Dominant grasshoppers were Psoloessa delicatula and Eritettix variabilis in the ungrazed plot and P. delicatula, M. sanguinipes, and A. elliotti in the grazed plot.

Tests in a screened insectary without temperature control at Mesa, Ariz., indicate that eggs of the differential grasshopper may hatch without exposure to low temperatures. Some of the eggs that were laid in March and April hatched in June. They were kept over moist sand in salve tins. Daily minimum temperatures during the incubation period ranged from 47° to 74°F.; maximum temperatures, 68° to 105° F.

Females of Melanoplus sanguinipes in insectary cages oviposited readily in sand moistened with water to 25, 50, 75, and 100% of saturation but did not lay eggs in air-dry sand when moist sand was available. This species was reared through 6 generations under laboratory-insectary conditions. More than 86% of the eggs of the sixth generation hatched, and the nymphs and adults were apparently normal in size and vigor.

Experiments conducted at Bozeman, Mont., showed that Melanoplus sanguinipes and M. bivittatus are extremely sensitive to the sterol content in their food. When the artificial diet was prepared with lettuce extract but without cholesterol, none of the test insects completed more than two of the normal five molts. Two analogs of cholesterol, cholesteryl acetate and dihydrocholesterol, were partially utilized as a sole sterol source. Diets containing these two analogs resulted in 10% of the test insects reaching adulthood versus 90% for a control diet containing cholesterol. However, cholesteryl chloride, a cholesterol analog having anti-cholesterol effects in some animals, was not utilized.

Subsequent tests were undertaken to see whether or not cholesteryl chloride would inhibit cholesterol utilization in Melanoplus. The artificial diet was prepared using the original amount of cholesterol and an equal amount of cholesteryl chloride. There was no detectable inhibition of growth in insects fed the diet containing cholesteryl chloride. The cholesterol could be reduced by three-fourths without inhibiting growth. This smaller amount was then used in a 1:1 ratio and a 1:10 ratio (cholesterol:cholesteryl chloride). The amount of cholesteryl chloride made little difference in the results and it was concluded that utilization of cholesterol was little influenced by cholesteryl chloride.

Investigations were continued at Bozeman, Mont., on the ecology of the grasshopper, Hesperotettix viridis, on Montana rangeland. Field observations indicated that hatching began in mid-June and continued until mid-July. Adults were found by mid-July. Mating began the first part of August and continued through September. Nymphs and adults were confined to areas containing numerous plants of snakeweek, Gutierrezia sarothrae. However, even in areas of heavy snakeweed concentrations the grasshoppers did not spread over the entire area but remained concentrated near the hatching places. Field-collected nymphs of all instars were successfully reared to adults in laboratory cages using clippings of snakeweed for food. The numphs and resulting adults fed mainly on the leaves and blossoms but would eat the bark if fresh food was not available. Also, dried clippings of snakeweed were accepted as food by older nymphs and adults.

Viable eggs were obtained from laboratory cultures of Hesperotettix viridus. Nymphs hatching from these eggs were successfully reared to adults on a diet of snakeweed branches and powdered snakeweed incorporated in an artificial media. Under laboratory conditions the average time from hatching to adult was 43 days. Adult life under laboratory conditions extended for 31 days.

Eggs obtained from first-generation laboratory-reared malformed adults of Melanoplus bivittatus were hatched and the grasshoppers reared in the laboratory. All of these second-generation grasshoppers reaching the adult stage were perfectly formed, lending additional support to the theory that the malformations are not genetic. In a subsequent experiment, using eggs from the same malformed parents, numerous individuals died shortly after becoming adults. Specimens sent to the Insect Pathology Laboratory have been determined to be infected with a fungus resembling Aspergillus flevus LK ex. Fr. In this group of grasshoppers an occasional malformed adult was observed. Since approximately 100% of the insects were diseased, with less than 1.0% being malformed, it appears that disease is not the cause of the malformations. Physical factors of the rearing procedure are still considered responsible.

2. Alfalfa Insects. Feeding tests with the alfalfa weevil were conducted at Beltsville, Md., using 47 different plants. Both larvae and adults fed on nearly all the true clovers, Trifolium spp., and on yellow and white sweetclover, Melilotus. Plants fed upon by adults but not by larvae were soybeans, mustard, rape, and black locust. Adults refused to feed on or lay eggs in one hop clover, Trifolium patens, when confined on it, but readily laid eggs in it when alfalfa or sweetclover was also available for food. This indicated the presence of a feeding deterrent and absence of an egg-laying deterrent in this clover. The presence of feeding and egg-laying stimulants has been demonstrated in ether and water extracts of fresh alfalfa. Partial success has been achieved in the formulation of an artificial diet by incorporating leaf extracts in an agar base.

Continuous laboratory rearing of weevils has been accomplished at Beltsville, Md., by maintaining larvae under short day lengths of 8 hours light. Under these conditions the diapause inherent in field populations is either lost or selected out in 2 generations. After the fourth generation, the time from adult emergence to first egglaying stabilized at 3 to 4 weeks. This makes possible the production of six generations per year in the laboratory as compared to one in the field.

Controlled matings at Beltsville, Md., between eastern weevils and weevils from four western locations substantiated results obtained in 1961. Western males crossed with eastern females produced infertile

eggs, while reciprocal crosses produced fertile eggs. The sex ratio of the "EW" hybrids was 8.5 females to one male as compared to the normal ratio of 1 to 1. Back-crosses are in progress to determine more clearly the degree of sexual isolation existing between the two populations.

Egg laying forms (sexuales) of the spotted alfalfa aphid were collected in 26 additional Nebraska counties in the fall of 1962 making a total of 49 counties in which these forms have been found. Sexuales were also reported from one county in Kansas and several additional counties in South Dakota. Egg hatching was observed during 1961, 1962, and 1963 and first instar nymphs were detected in mid-April. Populations began to increase during May but always declined before reaching economic levels. This decline appeared due to predator activity.

At Mesa, Ariz., damage to alfalfa seedlings by the leafhopper, Aceratagallia curvata, was studied using populations per plant ranging from 2 to 14 males, females, and sexes combined. Seedling mortality was greatest during the first 5 days of testing. Mortality caused by insect feeding decreased arithmetically from males, to females to sexes combined. Longevity of seedlings, infested with 2 to 14 leafhoppers per plant, ranged from 17.5 to 1.5 days, respectively.

3. Clover Insects. In 1962, at Lincoln, Nebr., early spring studies of the sweetclover weevil revealed that contrary to the previous year's findings, overwintered adults were most abundant at night. The second generation of weevils emerging in mid-summer displayed a strictly nocturnal habit. October populations were nocturnal for the most part but many weevils were also found during the day. Preliminary tests in the laboratory indicated that the weevil may be strongly nocturnal except when in a state of partial starvation. Under this condition the weevil is attracted to light in search of food.

Host range studies with the sweetclover aphid in the greenhouse at Lincoln, Nebr., revealed that all of the species of Melilotus available served to varying degrees as hosts. In the closely related plant genus, Trigonella, 8 of the 20 species tested were rated as non-hosts of the aphid. As far as is known the aphid does not have host species outside these two plant genera.

4. Grass Insects. Investigations were conducted in the sandhills area of Nebraska on a white grub, Phyllophaga anxia, that damages grasses in sub-irrigated hay meadows. The insect appears to have a 3-year cycle. In the spring of 1962, the majority of grubs were in the 3rd instar. Pupation began in late July and in mid-August beetles were found in the soil where they overwintered. Grubs burrow deeper into the soil in the fall and return to near the surface to feed in the spring. A definite relationship between grub populations

and soil moisture was observed. No grubs were found in the dry upland areas and populations were quite low in areas of excessively wet soil. Beetle flight, determined by using Japanese beetle traps, extended from May 25 to June 24. More beetles were caught in a wet meadow than in an upland area.

At Tifton, Ga., a black light trap caught 14 times more males than females of a bermudagrass spittlebug, Prosapia bicincta. Periodic sweeping of an area near the trap showed the population to be approximately 61% females, indicating that the trap had little effect on the sex ratio. In the spring the first newly emerged spittlebug nymph was found 21 days after soil temperature had reached and remained above 65° F. In the laboratory eggs required 17-21 days to complete their development when held in contact with moisture at 70° F. This spittlebug has been reported on a large variety of plants including such economic species as pangolagrass, St. Augustinegrass, coastal bermudagrass, and millet.

The bermudagrass mite, Aceria neocynodonis, was infesting Arizona common bermudagrass breeding plots at Tifton, Ga., in October 1962. A survey of other varieties and species of grass revealed no other infestations. In November adults, nymphs, and eggs were present beneath leaf sheaths. During December temperatures dropped to a low of 6° F. and no mites have been found since that time.

5. White-fringed Beetles. From 1958 through 1962 at Florala, Ala., a study was conducted to determine the difference in survival of white-fringed beetle larvae, Graphognathus leucoloma fecundus, in field plots planted to a winter crop as compared to the survival in plots without a winter crop, the rate of growth of larvae under these conditions, and the effect of population density on survival and rate rate of growth. All plots were planted to cowpeas each summer, and ryegrass was used as the winter crop. Each year in August or September the plots were infested with egg masses at the rate of 213, 426, 639, and 1,279 eggs per square foot. The larval populations, larval size, and depth of the larvae in the soil were determined in early February and early April each year. With each greater rate of infestation there was an increase in the larval population. At each examination and each rate of infestation the survival was greater in the plots provided with winter food plants. The winter food plants caused an average increase in survival for all rates of infestation of 81.3% in the February examinations and of 91.8% in the April examinations. An increase in larval size resulted from the supply of winter food, while higher rates of infestation caused a decrease in size. Winter food plants and the rate of infestation did not cause any appreciable difference in vertical distribution of the larvae in the soil.

B. Insecticidal and Cultural Control

1. Grasshoppers. During the winter of 1962-63, 50 new compounds were screened at Bozeman, Mont., using Melanoplus bivittatus and M. sanguinipes. The following 9 compounds were equal in toxicity to the aldrin standard: Hercules 7845C; Mobil MC-A-600; and Stauffer B-9340, B-9714, B-10204, B-10205, B-10341, R-5722, and N-4539. Seven of those tested equaled the aldrin standard at twice the dosage. These were: Monsanto CP 19203; and Stauffer B-9713, B-10175, R-5977, R-5723, R-5725, and N-2793.

In 1962, 5 compounds were field tested on 2-1/2-acre plots using ground equipment. American Cyanamid 43064 at 6 ounces per acre was superior to the aldrin standard. Bayer 39007 at 6 ounces per acre compared favorably with the standard, but General Chemicals 4072, at 8 ounces, Dibron 8E at 6 ounces, and Bayer 41831 at 8 ounces per acre were inferior.

Spray volumes of 1 pint to 1 quart per acre were applied to 40-acre rangeland plots by means of a Piper Pawnee airplane flying 100-foot swaths for grasshopper control. Comparisons were made between the Micronair Rotary Atomizer, Model AV-2000, producing droplets with an average diameter in the range of 84 microns and a standard boom arrangement producing droplets in the range of 150-200 microns. With the boom arrangement, 3/4 ounce of dieldrin in diesel fuel per acre gave kills of 79 to 99% at the 1-pint volume and 93 to 96% at 1 quart. A standard application of 3/4 ounce dieldrin in 1 gallon of diesel oil per acre gave kills of 94 to 97%. In the same series of tests the Micronair unit gave kills of 65 to 98% at the 1-pint volume and 80 to 98% at 1 quart.

In tests in eastern Montana with small aircraft (Piper Pawnee) on 40-acre range plots in 1962, Bayer 25141 in diesel oil at 2 ounces per acre gave kills equal to the aldrin standard. General Chemical GC-3707 applied as an emulsion gave kills equal to the standard at a dosage rate of 4 ounces per acre. Malathion at 8 ounces in emulsion was inferior to the standard. Dimethoate emulsion at 1 ounce per acre with additives of plyac, molasses, and ethylene glycol was inferior to the standard. However, the addition of plyac at 2 ounces per gallon increased the kill approximately 10%. Molasses at 1 quart per gallon of spray increased the kill by 6%, while ethylene glycol had no apparent effect.

In tests with Twin-Beech aircraft on 320-acre plots in eastern Montana, Bidrin, General Chemical GC-3707, and dimethoate, all at 2 ounces per acre, gave kills inferior to the aldrin standard. In the case of GC-3707 and dimethoate the kill was approximately 10% less than similar dosages applied by small aircraft. Since the flight height of the Twin Beech was 100 feet compared with 40 feet for the

Pawnee, it was theorized that the lower kill from the large aircraft might be due to greater loss through evaporation of the water emulsions.

In May 1963 in California, malathion was applied with a Stearman aircraft on 160-acre plots of rangeland. A new formulation consisting of 95% malathion per gallon was applied in panasol, an aromatic naphtha solvent, at 12 ounces in 1 quart per acre. An emulsion concentrate containing 8 pounds of malathion per gallon was applied at 12 ounces in 1 quart and one gallon per acre. Both formulations gave satisfactory kills.

2. Alfalfa Insects. At Beltsville, Md., applications of Geigy 30494 and Imidan, both at 1 and 2 pounds per acre on October 11 or November 13 failed to give satisfactory control of alfalfa weevil larvae the following spring. Heptachlor at 1 pound and Telodrin at .75 pound per acre gave good control. The addition of the adjuvant, Cellosize QP 4400, to 5 phosphate insecticides and methoxychlor decreased control as compared to the materials applied alone. However, EPN and methoxychlor applied as sprays at 2 and 3 pounds per acre, respectively, gave 88 and 82% control compared to 99% for heptachlor at 1 pound.

On November 14, 1962, applications of Telodrin at 1/4 to 1/2 pound per acre and heptachlor at 1 pound gave 96 to 100% control of alfalfa weevil larvae the following spring. Fall applications of methoxychlor gave fair control but applications of Guthion, EPN, and selica-gel were not effective.

In the spring of 1962 applications of Guthion and dimethoate with and without the adjuvants LS 0531, Sterox AA, Igepal CO 630, and Sun X223-5 showed no significant differences in alfalfa weevil control between Guthion and Guthion combinations, but the addition of Igepal CO 630 to dimethoate increased control significantly over dimethoate alone. Guthion alone, dimethoate plus Igepal, and heptachlor at rates of 0.5, 0.25, and 0.25 pound per acre, respectively, gave 80 to 85% control 20-days after application. The three promising insecticides Imidan, Geigy 30494, and Telodrin at respective rates of 1.0, 1.0, and 0.25 pound per acre gave 97 - 99% larval control 10 days after application. At 20 days after application, the percentages of control were 72, 84, and 94, respectively. Good control of the pea aphid was obtained with Geigy 30494 up to 10 days, and good control of the meadow spittlebug was obtained with Imidan and Telodrin up to 20 days. Of 10 experimental phosphate insecticides applied as sprays, 9 gave alfalfa weevil control equal to heptachlor at 10 days after application and 3 were only slightly less effective than heptachlor at 20 days.

Applications in the spring of 1963 were made to test materials previously screened in the laboratory for control of the alfalfa weevil. Experimental materials at 1 pound per acre that gave 95% or better control after 14 days were: GC 3707, GC 4072; Imidan; Bayer 25141; Amer. Cyan. 43064, 47470, 47031; CP 19203, 40296; and Hercules 6286. Shell 7438 at 1 pound gave 83% control at 14 days. Applications of Bacillus thuringiensis and the nematode DD 136 were not effective.

According to laboratory tests at Beltsville, Md., the alfalfa weevil has developed a high degree of resistance to heptachlor at several eastern and western locations. Collections from Logan, Utah, Lovelock and Fallon, Nev., Bozeman, Mont., Shell, Wyom., Clarksville and Westminister, Md., and Harrisonburg, Va., were resistant. No resistance was indicated in collections from Franklin, Tenn., Salisbury, N. C., Beltsville, Md., Moorestown, N. J., University Park, Pa., and Mitchell, Nebr.

3. Clover Insects. Results of 1962 tests in Nebraska again showed that plowing before spring regrowth had reached the bloom stage resulted in average reductions of 99% in the developing sweetclover weevil populations.

At Forest Grove, Oreg., fall and early winter applications of heptachlor granules at 12 to 16 ounces per acre gave 93 to 99% control of the clover root curculio. October applications of aldrin granules at 12 ounces per acre and dust mixture containing 32 ounces of methoxychlor and 13 ounces of malathion gave less than 30% control. The heptachlor granules also gave from 66-95% control of the lesser clover leaf weevil.

4. Grass Insects. At Tifton, Ga., phorate granules applied at 2 pounds per acre in June gave 100% control of the spittlebug, Prosapia bicincta, nymphs in 2 weeks and controlled adults over a 30-day period. Treated plots yielded more and better quality grass than untreated plots. Granular applications of carbophenothion, endosulfan, and Sevin and spray applications of Di-syston and dimethoate did not give satisfactory control.

Several insecticides were tested at Tifton for the control of the fall armyworm on bermudagrass and pearl millet. Diazinon and Guthion gave fairly good control at one pound per acre; Sevin at 2 pounds per acre gave about 80% control. Zectran gave good control at 4 ounces per acre and spray formulations gave better control than granules. Endosulfan was less effective than other insecticides tested.

Samples of grass from plots treated with Imidan at 4, 8, and 16 ounces per acre, were fed to 3-day old fall armyworms in the laboratory at Tifton, Ga. One day after application samples taken from the 16-ounce level produced 100%, from the 8-ounce level 49% and from the 4-ounce level 34% mortality in 24 hours.

5. White-fringed Beetles. At Florala, Ala., pot tests exposed to outdoor weather and temperatures were conducted with Sevin, Hercules 5727, American Cyanamid 24055, diazinon, American Cyanamid 18133, Telodrin, and Bayer 29852, to determine their effectiveness as soil insecticides for the control of white-fringed beetles. These materials were used at rates of 0.5, 1, 2.5, 5, and 10 pounds in 403.3 cubic yards of soil, the upper 3 inches of an acre. Telodrin was highly effective against newly hatched white-fringed beetle larvae, all dosages giving complete mortality. The other materials were not effective at the highest dosage used.

In outdoor soil chambers, aldrin, dieldrin, and heptachlor were mixed into the upper 3 inches of soil in July 1957 at rates of 0.5, 1, 3, and 5 pounds per acre. These chambers have been infested each year with newly hatched white-fringed beetle larvae. In 1961-62, the 0.5-pound dosage of aldrin gave 97% and the 1-pound dosage of heptachlor gave 98% control, while all other dosages gave complete mortality.

Granular application of dieldrin and heptachlor at 3 and 5 pounds per acre and emulsion at 5 pounds of the insecticides per acre on the soil surface around established azalea and camellia plants at Florala failed to eliminate all white-fringed beetle larvae. However, dieldrin has given better control than heptachlor.

C. Insecticide Residue Determinations

1. Endosulfan Residues. Coastal bermudagrass at Tifton, Ga., treated with endosulfan emulsion at 0.25, 0.50, and 1.00 pound per acre contained 0.98, 1.95, and 7.07 p.p.m. residues, respectively, when cut 7 days later. On the 78th day after ensiling, the residues in the silage were 0.37, 0.56, and 2.45 p.p.m. for the 0.25, 0.50, and 1.00 pound treatments. Analysis of milk from dairy cows fed the silage, with samples taken at intervals of 1, 3, 6, 13, 20, and 28 days of feeding, showed no detectable residues.

Endosulfan as an emulsion spray was applied at 1.8 pounds per acre to three 2-acre pastures of coastal bermudagrass. An untreated pasture served as a control. Samples of grass taken at intervals after treatment showed up to 0.36 p.p.m. endosulfan 71 days after treatment. Three beef animals were placed on one of the treated pastures at intervals of 1, 7, and 13 days after treatment and grazed for 31, 35, and 36 days, respectively. Animals were grazed for 31 days on the control pasture. Residues on the grass during the grazing

periods ranged from 32.80 to 1.30 p.p.m., 5.76 to 0.75 p.p.m., and 3.50 to 0.77, for the 1, 7, and 13-day waiting periods. Chemical analysis of fat samples obtained by biopsy from the exposed and control animals indicated that no endosulfan was present.

Endosulfan was incorporated into rye silage at 10 and 100 p.p.m. and placed in gallon jars. Analysis indicated that residues remaining after 11 weeks of storage were approximately 40% of the initial amounts added to the silage.

2. Phorate Residues. In the greenhouse at Tifton, Ga., phorate residues in foliage toxic to Drosophila melanogaster adults were detected significantly sooner after application to soil surface than from a water emulsion of the same insecticide injected into the root zone. Residues resulting from granular heptachlor, surface applied, were not detected significantly sooner than those of phorate emulsions injected into the root zone.

3. Heptachlor Residues. At Forest Grove, Oreg., red clover was treated with 2-1/2% granular heptachlor at the rates of 1/4 and 1 pound of heptachlor per acre. Samples taken 4 months after treatment and analyzed at Yakima, Wash., contained measurable amounts of heptachlor but no measurable amounts of heptachlor epoxide. Red clover treated with 1 pound of heptachlor as an emulsifiable concentrate and harvested 6 months later did not contain measurable amounts of heptachlor or heptachlor epoxide.

D. Biological Control

1. Grasshoppers. At Bozeman, Mont., laboratory and field studies were initiated to ascertain the effect of the protozoan disease, Nosema locustae, on grasshoppers. During the summer of 1962 the organism was found in grasshoppers collected in Minnesota, eastern Montana, and southern Idaho. Infections of this organism have occurred in at least 11 species of grasshoppers. The disease reduces rate of development, increases death rate and reduces weight of adults.

In Montana and Idaho, species of Tachinidae, Sarcophagidae, and Nemestrinidae were found parasitizing grasshoppers. Mermithed worms were common during the early summer. A fungus resembling Aspergillus flavus produced high mortality rates in Camnula pellucida collected near Fernwood, Idaho, and Lamedeer, Mont. The same fungus produced high mortality rates in some laboratory-reared Melanoplus bivittatus. Efforts to isolate viruses from grasshoppers have been unsuccessful.

The life history of the parasitic grasshopper mite, Eutrombidium sp., was studied at Columbia, Mo. The pre-oviposition period averaged 13.8 days. The average time from egg laying to the deutovum stage was 8.2 days, and final hatching occurred about 10.5 days later. The larvae searched out and attached to available grasshoppers where they remained for an average of 22.2 days. After engorgement the mites underwent a pre-nymphal, quiescent period which averaged 21.3 days. The nymphal period was about 32 days during which time the mites fed readily. Preimaginal pupation required about 17 days whereupon the adult emerged. Females produced an average of 2.7 egg masses.

Erythraeid mites identified as Leptus sp. were recovered from Melanoplus differentialis and M. femur-rubrum which were sent to Columbia from Wooster, Ohio. Larvae attached to nearly all parts of the grasshoppers where membranous areas were present, especially at the base of the hind wings. Detached engorged larvae were mobile, six-legged, hairy creatures, red-orange in color and 1 to 1.5 mm. in length. The life cycle required about 127 days. Both the nymphs and adults fed readily on grasshopper eggs.

2. Spotted Alfalfa Aphid. Aphelinus semiflavus and Praon palitans, imported parasites of the aphid, were not observed in Arizona in 1962. However, the latter species was observed in one field in 1963. The known State range of Trioxys utilis, a third imported parasite of the aphid widely established in central and southern Arizona by 1961, was not extended according to surveys made in 1962. In 1962 parasitization by T. utilis was observed in only two fields and averaged less than 1% but this parasite was more widely distributed and abundant in 1963.

Observations on the spotted alfalfa aphid and its natural enemies were continued bi-weekly in 1962 in 4 untreated alfalfa fields near Mesa, Ariz. Compared with 1961 there were moderate to large increases in such predators as beetles, nabids, geocorids, syrphid fly larvae, and lacewing fly larvae, a slight increase in Orius spp., and a slight decrease in Collops vittatus.

3. Alfalfa Weevil. The alfalfa weevil has continued to spread in the Eastern States and now occurs throughout the Eastern alfalfa growing areas from Mississippi and Arkansas, northeast through Ohio, to southern New Hampshire and Vermont. Parasites, primarily Bathyplectes curculionis, were released on 4 lines extending northwest from origins in Georgia, North Carolina, New Jersey, and Massachusetts. Of 24 releases made in 1961 and 1962, the parasite has been recovered from 23; the 24th site was not sampled. Five additional releases were made in 1963 in newly infested areas of Tennessee, Ohio, and New York.

Several other introduced parasites have been released. Tetrastichus incertus released in 1961 in 9 sites in 5 States and at 2 sites in 1962 was recovered in Chester County, Pa., in 1962. Dibrachoides druso released at 4 sites in 3 States in 1961 and at 2 sites in 1962 has not been recovered. Peridesmia discus released at 1 site in 1961 has not been recovered. A small release of Microctonus aethiops was made in 1963 at Raleigh, N. C. This parasite has become established in New Jersey where it was released several years ago. Bathyplectes anura was released and recovered the same season at one site in Pennsylvania.

A native egg parasite, Pattasson luna, was reared from alfalfa weevil eggs collected at Beltsville, Md., in April and May 1962. Under laboratory conditions adult parasites were able to parasitize only newly laid undeveloped host eggs. Parasite development from oviposition to adult emergence was completed in 10 days.

A preliminary field cage test at Beltsville, Md., was conducted in 1962 to determine the relative numbers of Bathyplectes needed to control the weevil in a single season. Parasites were introduced at the rates of 5 pairs, 2 pairs, and 1 pair per 500 host larvae. There were obvious differences among treatments in amount of leaf damage and number of weevils maturing but complete control was not achieved. The host population in terms of adults produced was reduced 60% by 5 pairs of parasites and the rate of parasitism was 14.3% based on beginning larval populations and number of parasite cocoons recovered.

4. Grass Insects. Preliminary field and laboratory tests at Lincoln, Nebr., indicated that grubs of Phyllophaga anxia from the Nebraska sandhills are susceptible to milky disease. Spore powder was applied to field plots on May 22, 1962, and on November 7, diseased third instar grubs were found. One diseased grub was approximately 10 feet from where the spore powder was applied. In the laboratory, third instar grubs became milky when placed in infected soil with suitable food. Healthy grubs were readily infected by injecting with blood from diseased grubs. Grubs of this species were attacked in the field by a naturally occurring fungus, Metarrhizium anisoplia, and a naturally occurring insect parasite, Microphthalma michiganensis. The incidence of both of these control agents was extremely low. A mite, Caloglyphus sp., was found abundantly in association with the grubs but was determined to be a scavenger.

5. Armyworms and Cutworms. Due to unusual cold and prolonged drouth conditions the armyworm and fall armyworm populations were very low in Louisiana. A few larvae of possible alternate hosts of armyworm parasites were collected. One of these yielded an armyworm parasite, apparently Meteorus autographae, and another two specimens believed

to be Apanteles marginiventris which attacks the fall armyworm.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. White-fringed Beetles. At Florala, Ala., studies of the attractiveness of certain plants to white-fringed beetle adults were continued in 1962. Field-collected adults were released in the center of an outdoor cage, 24 by 24 feet, where they had a free choice of movement. Peanut, sicklepod, and cocklebur plants covered with double screen wire cages to prevent beetles from feeding on the foliage, and cages without plants, were placed near the outer edge of the large cage. The adults found on the small cages were removed 3 times each day. Slightly more beetles were found on the cages containing plants than on the empty cages. Cages containing plants infested with beetles were more attractive than cages containing plants without beetles.

In other tests one hill of peanuts was planted in the center of 80 hills of corn in a cage 30 by 30 feet in size. Field-collected adults were released at the 4 corners of the area, or 15.5 feet from the peanut plant. The beetles found at the peanut plants were removed three times each day. From July 17 to August 20, 3,100 adults were released in 2 test areas and only 10.1% were recovered at the peanut plants. Apparently the adult does not possess the ability to detect a favored host plant by smell or sight.

F. Evaluation of Equipment for Insect Detection and Control

1. White-fringed Beetles. Tests were begun at Florala, Ala., in 1960 to study the relative effectiveness of strip and broadcast applications of certain insecticides against white-fringed beetles on noncultivated land. A special applicator was used that applied granular formulations of insecticides in narrow bands 12 inches apart on the soil surface in such a manner that the insecticide would not come in contact with the plant foliage. The plots were treated in October 1960 and infested with egg masses in 1960 and 1961. Larval populations were determined in April 1961 and again in April 1962. Aldrin, chlordane, dieldrin, heptachlor, and Sevin were used at 2 or 3 rates. Sevin was not effective as a surface treatment. The broadcast applications gave better control than the strip applications during the first year following treatment, but during the second year both types of treatment were equally effective. This machine disturbed the surface of the soil thereby enabling newly hatched larvae to penetrate the soil more readily. This factor caused a greater survival in all plots treated with the machine than in the plots receiving broadcast applications in the first year following treatment but not in the second year. In plots which received no insecticide the soil disturbance from the machine caused a 91% increase in survival over that which occurred in untreated

nondisturbed plots in 1961, and a 60% increase in 1962. The smaller dosages of aldrin, chlordane, dieldrin, and heptachlor were less effective than the larger dosages.

G. Varietal Evaluation for Insect Resistance

1. Spotted Alfalfa Aphid. Sonora, a new non-dormant spotted alfalfa aphid resistant variety developed in the cooperative alfalfa improvement program in Arizona, California, and Nevada, was released in 1962. The variety is adapted to the lower desert valley areas of Arizona, California, and southern Nevada and presumably to areas in northern Mexico which have similar growing conditions.

At Mesa, Ariz., 18 alfalfa plants, progenies from four clones of Chilean 21-5 selected for resistance to the spotted alfalfa aphid, were caged tested for antibiosis and 14 rated highly resistant. This indicates that it may be possible to develop a resistant variety from Chilean 21-5.

Studies on the spotted alfalfa aphid at Mesa, Ariz., showed that mortality of infested seedlings of resistant and susceptible alfalfa varieties was the same up to 15 days following germination. This suggested that certain mechanisms of resistance were not operating during this critical period, and insecticidal treatment of resistant varieties may be needed in the seedling stage if populations of aphids are high.

At Tucson, Ariz., seedlings of 13 synthetic combinations, constituted by members of the Southwest Alfalfa Group, were evaluated for resistance to biotypes ENT A and ENT B of the spotted alfalfa aphid. Resistant Moapa and Sonora were used as checks, and 3 commercial varieties were also included. Outstanding synthetics were SW-12 and SW-13, both California combinations. SW-12 was rated best in ability to make growth following infestation, and SW-13 gave top performance in plant survival (78%). Also excellent in plant survival was SW-17 (74%), a two-clone Arizona combination, and SW-21 (66%), a California coastal and high desert combination.

At Lincoln, Nebr., seedling progenies of aphid resistant and aphid susceptible clones were mass infested with parthenogenetic forms of the sexuale-producing strain of the spotted alfalfa aphid. Plants resistant to the solely-parthenogenetic strain of the aphid were also resistant to the strain which has the ability to produce sexuales. Aphids from neither strain lived much longer than 3 days when confined to resistant plants, indicating that apparently there are no basic differences between the two strains in regard to host plant resistance.

2. Lygus Bugs. At Mesa, Ariz., the screening of 2,000 alfalfa plants representing several varieties and experimentals resulted in selection of 36 with moderate promise for resistance to lygus bugs. Most of these plants had some damage, and none showed the marked reaction desired for breeding resistance into new varieties.

3. Alfalfa Seed Chalcid. Fifty-four varieties of alfalfa at Yuma and 48 at Mesa, Ariz., were evaluated for resistance to the alfalfa seed chalcid. Among entries having the lowest mean infestation at Yuma were A-224, Orestan, Chilean 21-5, and New Mexico 11-1, and at Mesa, Zia, Williamsburg, Rambler, and Talent. Lahontan, which showed promise in earlier tests, ranked 8 and 13 in the Yuma and Mesa studies, respectively. Among 5 clones which comprise the variety Lahontan, clone C-89 had the lowest chalcid population in two separate tests. Apparently this clone contributes most to the slight resistance in Lahontan to the alfalfa seed chalcid.

Over 2,000 individual plants from 18 different sources were screened for resistance to the chalcid in tests at Mesa. Nearly 300 plants were selected from this group on the basis of having less than 30 chalcids per raceme. Most of the promising material was selected from the two-clone combinations in which M-56-11, an important source of chalcid resistance, was crossed with three high-yielding selections out of African.

4. Pea Aphid. At Lincoln, Nebr., research is continuing in the development of combined pea aphid and spotted alfalfa aphid resistance. Nebraska synthetic 27, whose parents had been selected for resistance to both aphids in greenhouse tests, showed a high level of pea aphid resistance under a heavy aphid infestation in a field cage. In general there was close agreement between greenhouse and field cage results with all plants tested.

At Poznan, Poland, (P. L. 480 project E21-ENT-9) two preliminary tests showed some antibiosis of lupine plants to the pea aphid. In the first test Gorki (yellow), Wielkopolski (blue) and Przebedowski (white) revealed some resistance as measured by extremely low aphid reproduction. The second test with 12 varieties confirmed these results and revealed similar resistance in varieties Osbornicki (yellow) and Przebedowski Wczesny (white).

5. Potato Leafhopper. Counts were made at Lincoln, Nebr., of adult and nymphal populations of the potato leafhopper on established varieties, plant introductions, and experimental synthetics of alfalfa at peak leafhopper infestation during mid-July. No correlation was found between leafhopper populations and a system of visual rating based on the degree of plant yellowing. There is apparently no difference in attractiveness to the potato leafhopper among these alfalfas, and differences in degree of plant yellowing are probably due to tolerance.

At University Park, Pa., 15 selected alfalfa clones were tested in the greenhouse, laboratory, and control chamber to determine percent egg viability, time for nymphal development, and plant preference of potato leafhopper nymphs. There were significant differences for length of nymphal development and nymphal feeding preference. Males developed approximately one day sooner than females. These same clones were replicated in a spaced nursery and half of them were sprayed. A plant color rating and nymphal count on the unsprayed clones showed a significant correlation. This may not be a true relationship, however, because adults are attracted to yellow, and therefore to yellowing alfalfa. A comparison of the dry weights of injured and sprayed top growth showed that color and stunting are not always related. In order to measure antibiosis, unaffected by yellowing, potted clones from the greenhouse were exposed briefly to egglaying in the field, and were then returned and held 19 days while nymphs hatched and developed. Results showed significant population differences among the clones that were unrelated to either color or dwarfing. Yellowing, dwarfing, and antibiosis were unrelated but important factors that should be evaluated in selecting plant material for resistance to the potato leafhopper.

6. Alfalfa Weevil. At Beltsville, Md., four alfalfa nurseries containing 151 entries were rated for larval damage in 1961 and 1962. Entries with the lowest damage ratings for the 2-year period were species of Medicago falcata, several entries of the variety Narragansett, and plant introduction numbers 151671, 212798, 213394, 234482, and 235821. Only the variety Narragansett is agronomically suitable for hay production. On the basis of correlations between damage ratings and measurements of plant characteristics there was a tendency for profuse stem branching, slow recovery after cutting, and yellow or variegated flowers to be associated with low damage ratings. These characteristics are typical of M. falcata.

No significant differences were found among 106 alfalfa entries in laboratory and greenhouse tests designed to measure larval damage on uncaged potted plants, larval survival and weight on cut caged stems, or larval survival on stems caged over potted plants. In these tests initial infestations were obtained by using known numbers of eggs or newly hatched larvae. A highly significant correlation of 0.3722 was found, however, between the number of eggs laid per inch of stem in the laboratory and larval field damage ratings. This egglaying preference test utilized cut stems in water in a common cage containing mature weevils. Additional egglaying preference tests were made with 24 entries selected to represent the range of differences observed in the entire group, and in addition, stems were rated for adult feeding damage and measured for stem diameter. Correlations between average performance ratings or measurements for these 24 entries gave highly significant values of 0.7613 between field larval damage ratings and egglaying preference in the laboratory, 0.6111 between field damage

and stem diameter, 0.5980 between stem diameter and egglaying, and 0.5694 between stem diameter and adult feeding. Thus either or both stem diameter and feeding preference appear to be closely associated with egglaying and resulting larval damage.

7. Sweetclover Aphid. At Lincoln, Nebr., 98 accessions of plant introductions of sweetclover, provided by the Crops Research Division, were screened for sweetclover aphid resistance. None of these accessions were uniformly resistant but a number of them contained one or more resistant plants. The lines from which resistant plants were selected came from many different areas of the world. The accession (PI-178985) producing the greatest number of resistant plants was of Turkish origin. Heritability of resistance in the majority of the selections was confirmed by testing selfed-progeny.

8. Sweetclover Weevil. Sweetclover weevil larval populations were determined in a field nursery containing 4 common varieties, Spanish, Denta, Madrid and Goldtop, and one experimental, N-13. The mean number of larvae per square foot of soil ranged from 28.6 for Spanish to 58.7 for Denta but these differences were not statistically different.

Since practical levels of resistance to the sweetclover weevil have not been uncovered in the screening of varieties and lines, screening tests were conducted at Lincoln, Nebr., on all of the available species of the sweetclover genus, Melilotus, and a closely related genus, Trigonella. One species of Melilotus was nearly immune to feeding by the adult weevil. It is hoped that this species can be crossed with the common sweetclover species.

H. Insect Vectors of Diseases

1. Vectors of Red Clover Root Rots. At University Park, Pa., studies were made to determine whether the control of root weevils and root rots would increase the longevity of red clover stands. Plots were sprayed periodically with insecticides and fungicides singly and in combination during the seedling, first, and second year. At the beginning of the third harvest-year (or fourth year) the percent of ground cover for check plots averaged 1; fungicide plots 1; insecticide plots 45; and combined fungicide-insecticide plots 45.

Results of a greenhouse experiment made at University Park, Pa., showed for the first time that larvae of Calomycterus setarius fed on small rootlets of red clover, and when full-grown, gouged the top and lateral roots. The crown and root weights of weevil-damaged plants were less than those in the controls. Of the 4 treatments--control; soil infested with C. setarius; with Fusarium spp.; and with both C. setarius and Fusarium spp.--most root rot developed on plants given the last treatment, with small differences among those in the other treatments.

2. Tumors on Alfalfa. At University Park, Pa., an alfalfa plant with tumors was found during tests for resistance to potato leafhoppers. The tumors occurred at the feeding sites on stems, petioles, and leaves. The epidermis usually ruptured within 42 to 48 hours after feeding by nymphs or adults and the growth development terminated within 5 days. Tumors could be produced artificially by pricking leafhopper body juices into the plant tissues with a needle. Heat and formalin used to destroy virus did not affect tumor growth.

3. Insect Vectors of Lupine Diseases. Continued studies at Tifton, Ga., of aphid abundance on yellow lupine after treatments with granular phorate and emulsion sprays of dimethoate, at 2 pounds of the insecticide per acre indicated (1) that the insecticides persisted in the plants, as determined by comparative biological assays utilizing Drosophila melanogaster adults; (2) that aphid populations were greatly reduced after both treatments; and (3) that the reduction of aphids was associated with a reduction in bean yellow mosaic virus in the plants.

4. Vectors of Lupine Viruses. At Poznan, Poland, research under P. L. 480 project, E21-ENT-9 in which the green peach, bean, and pea aphid were used as vectors, double transmission of bean yellow mosaic virus and cucumber mosaic virus from infected to healthy lupine plants was successful only with the green peach aphid. The other aphid species transmitted each of the viruses singly but never both simultaneously. The green peach aphid was the most efficient vector, followed by the pea aphid and the bean aphid.

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AREA NO. 6. SOYBEAN AND PEANUT INSECTS

Problem: Soybeans and peanuts are severely damaged by several insect pests in the different areas where these crops are grown in the United States. The increasing concentration of acreage in soybeans and possibly the adaptation of native insects to this crop are resulting in more varied and more serious insect problems. In the absence of specific support for research on soybean insects, some shifts in emphasis have been made to investigate some of the problems. However, basic information is lacking on the biology of many of these pests and on the extent and nature of damage they cause to these crops. Such information is needed to serve as a foundation for the development of satisfactory control methods. Some insecticides, although highly effective in controlling insects on soybeans and peanuts, cannot be used because they leave harmful residues. Further, certain insects have developed resistance to insecticides that are currently recommended. For the immediate future, there should be continued effort to find insecticides that can be used safely and that give effective, economical control of all species of insects attacking these crops. For more desirable long-range solutions to the problems, more attention needs to be given to nonchemical control methods, with particular emphasis on insect-resistant crop varieties and biological control agents and the exploration of new chemical approaches such as attractants and repellents.

USDA PROGRAM

The Department has a limited program involving basic and applied research on the insect problems of peanuts and soybeans directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists and chemists. Studies on soybean insects are conducted at Columbia, Mo., and on soybean and peanut insects at Tifton, Ga., in cooperation with the Missouri and Georgia Experiment Stations.

The Federal scientific effort devoted to research in this area totals 1.5 professional man-years. Of this number 0.3 man-year is devoted to basic biology; 0.3 to insecticidal control; 0.5 to insecticidal residue determinations; and 0.1 to biological control; 0.1 to varietal evaluation for insect resistance; 0.1 to insect vectors of diseases and 0.1 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology

1. Soybean Insects. Screen cages were utilized at Columbia, Mo., to study the effect of stink bug damage, pod removal, and simulated stink bug punctures on soybean production and maturity. There were no significant differences in the number of pods set on plants in uninfested cages and in cages in which 4 pairs of Euschistus servus stink bugs were present, 8 E. servus male bugs were present, or where pods on the lower half of the plant had been pierced with sterile minuten needles to simulate stink bug injury. Where pods on the lower half of caged plants were removed, the number of pods remained significantly less than in the other treatments. There was no difference in number of damaged beans between treatments containing 8 male stink bugs and simulated damage to the lower half of the caged plants. Cages containing 4 pairs of stink bugs showed a significantly greater damage than all treatments primarily because of reproduction within these cages. The number of undeveloped seeds increased in the treatments in the following order: Pods removed, check, pierced pods, eight male stink bugs, and four pairs of stink bugs.

B. Insecticidal Control

1. Soybean Insects. Results of field tests in Missouri to evaluate the effectiveness of Sevin, Guthion, toxaphene, malathion, and methoxychlor showed no significant differences in yield of soybeans or in the number of damaged beans in any treatment from the check. Lack of concrete results may have been partially due to poor timing of insecticide applications which were made too early with respect to stink bug infestation.

At Tifton, Ga., diazinon, Zectran, Guthion, endosulfan, and Sevin at 4, 8, and 16 ounces per acre, were applied to soybeans which were in a late blooming stage with some pods formed. Counts of Mexican bean beetle larvae and adults and corn earworm larvae were made 5 days after treatment. Diazinon gave approximately 71% control of the Mexican bean beetle. The 16-ounce rate gave 68% control of the corn earworm. Zectran gave 95-97% control of the Mexican bean beetle. The 4-, 8-, and 16-ounce rates gave 65, 93, and 98% control of the corn earworm. Guthion at these rates gave 46, 57, and 96% control of the corn earworm. Endosulfan at 4, 8, and 16 ounces, gave 43, 80, and 85% control of the Mexican bean beetle and 9, 45, and 66% control of the corn earworm. Sevin gave better than 85% control of the Mexican bean beetle at all rates. At 4, 8, and 16 ounces per acre, this insecticide gave 56, 73, and 93% control of the corn earworm.

Granular dieldrin, ethion, Dylox, Bayer 29493, and 4 formulations of Sevin were tested at Tifton for control of the lesser cornstalk borer

on seedling soybeans. The formulations of Sevin were: (1) Water impregnated on vermiculite with a water repellent coat, (2) water impregnated on basic clay with a water repellent coat, (3) acetone impregnated on acid clay without coating, and (4) acetone impregnated on basic clay without coating. All were applied at two pounds per acre. The water impregnated formulations of Sevin were also applied at a one pound rate. They were applied in an 8-inch band over rows of soybeans in the 2-leaf stage. Dieldrin, Bayer 29493, Dylox, and ethion provided effective control of the insect and differences between them were not significant. All Sevin formulations, at the rates tested were ineffective.

C. Insecticide Residue Determinations

1. Residues of Endrin and Chlordane on Peanuts. At Tifton, Ga., peanuts were treated with granular formulations of chlordane at 4 pounds per acre and endrin at 2 pounds per acre. Applications were made at pegging time, July 23, 1962, in a 14-inch band over the row. The peanuts were harvested October 24, and air dried for 2 months. The residues on dried whole peanuts from the chlordane-treated areas averaged 1.74 p.p.m. chlordane and in addition 0.19 p.p.m. heptachlor epoxide. The chlordane granules by analysis contained a small amount of heptachlor, 0.48%, but no heptachlor epoxide was detected. Residues of endrin averaged 0.81 p.p.m.

D. Biological Control

1. Parasites of Lesser Cornstalk Borer. Parasitism of lesser cornstalk borer larvae attacking seedling soybeans and cowpeas may exceed 50% of the larval population. Parasites collected at Tifton, Ga., were Pristomerus pacificus melleus, Orgilus n. sp., and Stomatomyia floridensis.

E. Varietal Evaluation for Insect Resistance

1. Stink Bug. Results of varietal evaluation at Columbia, Mo., of soybeans with respect to damage by stink bugs indicated that differences were principally due to date of maturity rather than other inherent differences in 12 varieties tested.

F. Insect Vectors of Diseases

1. Transmission of "Yeast Spot" of Soybeans by Stink Bugs. In studies at Columbia, Mo., stink bug damage to soybeans resulted principally from the introduction of the yeast, Nematospora coryli, which causes "yeast spot" disease. This yeast was isolated in the laboratory in Columbia in the fall of 1962. Tests with laboratory grown plants proved the capability of this organism to cause the disease. Re-isolation of the organism has been repeatedly demonstrated

in both artificially inoculated and stink bug damaged soybeans. The organism has been isolated from the macerated heads of Euschistus servus and transmitted to soybeans. In cage tests in the field the disease organism was not transmitted through artificial puncturing of the pods but was readily isolated from caged plants and pods which had been associated with the brown stink bug. Both the brown stink bug (E. servus) and the green stink bug (Acrosternum hilare) transmit N. coryli to soybeans.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

A. Basic Biology, Physiology, and Nutrition

Blickenstaff, C. C. and Huggans, J. L. 1962. Soybean insects and related arthropods in Missouri. Mo. Agr. Expt. Sta. Bull. 803. 51 pp.

B. Insecticide Residue Determinations

Beck, E. W., Dawsey, L. H., Woodham, D. W., Leuck, D. B., and Morgan, L. W. 1962. Insecticide residues on peanuts grown in soil treated with granular aldrin and heptachlor. Jour. Econ. Ent. 55:953-956.

AREA NO. 7. CORN, SORGHUM AND SMALL GRAIN INSECTS

Problem: Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of $900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. Recently, the sorghum midge has become a more important pest of sorghum in the Southwest. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in 46 counties in Michigan, Indiana, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to stunt diseases recently found in Ohio and several Southern States, indicate the importance of research in this field.

USDA PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect

transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on hessian fly, wheat jointworm, and cereal leaf beetle at West Lafayette, Ind., and Manhattan, Kans.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Minot, N. Dak., Brookings, S. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and West Lafayette, Ind.; fall armyworm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Manhattan, Kans., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Additional research is being conducted under ARS contracts, on the biology and control of the cereal leaf beetle with Michigan State University, and on soil insects attacking corn with the University of Nebraska.

The Federal scientific effort devoted to research in this area totals 36.5 professional man-years. Of this number 9.2 is devoted to basic biology, physiology, and nutrition; 4.5 to insecticidal and cultural control; 3.0 to insecticide residue determinations; 3.6 to biological control; 2.3 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 10.7 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" is underway at the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of The Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize With Special Reference to Stalk Borers."

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. Population studies on European corn borer in Boone County, Iowa, in the spring of 1963 showed that overwintering borers averaged 3,187 per acre. Pupation began May 15, 1963, and first brood oviposition June 2. The population of the first brood averaged 15 borers per 100 plants. The 1962 fall population had averaged 105 borers per 100 plants, and 4833 borers per acre.

Experiments at Ankeny, Iowa, designed to study the factors influencing mating of European corn borer moths indicated that maximum mating (100%) can be obtained in 48 hours under laboratory conditions by alternating temperatures from 85° F. (day) to 65° F. (night), and maintaining a light period of 14 hours in length for each 24-hour period.

A study initiated at Wooster, Ohio, to study single-generation and multiple generation strains of the European corn borer, showed that the diploid number of chromosomes was 62.

Diet and light studies in laboratory tests on the European corn borer, at Ankeny produced the following results: (1) Corn borer larvae reared on artificial media will go into a false diapause if subjected to 13-1/2 hours of light daily. (2) Deterioration of leaf factor materials stored in a refrigerator can be prevented by adding supplementary vitamins. (3) Dietary shortages lead to morphological deformities. (4) A completely defined diet is necessary to study nutritional diseases of the European corn borer.

At Brookings, S. Dak., it was determined that susceptible strains of the southern corn rootworm metabolized aldrin to dieldrin while the resistant strain metabolized aldrin to an unknown compound. The resistant strains required about 3 times as much aldrin as the susceptible for an LD_{50}. The western corn rootworm metabolized aldrin in a similar manner.

At Tifton, Ga., the quantity of Telodrin required internally to produce mortality of first-instar corn earworm larvae ranged from 1.19 to 5.59 p.p.m., and of third-instar larvae, from 5.86 to 6.05 p.p.m.

The corn earworm caused an estimated $3,100,000 loss to corn in Georgia, Florida, Alabama, North Carolina, and South Carolina, in 1962, and was found in every field examined during a survey in these States. The pink scavenger caterpillar was found in 99% of the fields, the rice weevil in 90%, and the fall armyworm in 5%. In Mississippi over 56% of the ears were infested by the corn earworm, causing an estimated loss of $543,000. Extremely heavy fall armyworm populations caused

a complete crop failure in late-planted corn. About 89% of the ears were infested with the pink scavenger caterpillar. The southwestern corn borer now occurs in all agricultural districts of Mississippi except the south-central district, infesting nearly 40% of the fields.

In a study of corn earworm larval feeding habits in a resistant (F44 x F6) and a susceptible (Mp316 x Mp319) single cross at State College, Miss., the larvae preferred silks to kernels for food and in some instances chose silks for the entire feeding period. They also fed more on hybrids having high percentages of reducing sugars than on those with low percentages of such sugars.

At Tifton, Ga., measurements of the circadian rhythm of the corn earworm indicated definite periods of night flight that are not dependent on light changes. Photoelectric-photograph analyses of moth flight showed that noctuid moths are much more maneuverable than sphingid moths, with a greater degree of aerodynamic lift at a lower angle of attack. Leg appendages are used for flight stabilization. Antennae are fairly stable in level flight. Noctuid antennae tend to bend under aerodynamic stress, e. g., during loops or steep climbs, while sphingid antennae remain fixed and rigid under the same stress.

At Tifton, Ga., morphological and light trap population studies indicated that the first April-May corn earworm flights are of major economic importance. The early population probably represents an efficient overwintering population since the percentage of mating of this flight is far above the yearly average.

At Stillwater, Okla., the percentage of stalk girdling by the southwestern corn borer was higher and the yield lower in late-planted than in early-planted corn. Also, the percentage of borer girdling and stalk lodging increased and the yield decreased as harvest was delayed. Machine harvesting in infested corn resulted in lower yields than hand harvesting, largely because of the failure of the harvester to recover lodged stalks, the majority of which were girdled by the borer.

In southeastern South Dakota and northwestern Iowa, resistant strains of the western corn rootworm were observed in fields which had been treated with chlorinated insecticides. Some of the strains were 40 times as resistant as the strain collected from untreated areas. Damage to corn by the northern corn rootworm was moderate when larval populations developing to adults numbered 70 per plant.

Adult emergence of the northern corn rootworm at Brookings, S. Dak., extended over a six-weeks period beginning August 1. Maximum emergence occurred August 15-25.

At Brookings, the southern corn rootworm has been reared through six generations in the laboratory. Adult beetles in cages fed on young squash leaves, and on an artificial diet of honeybee pollen substitute, fine corn meal, water, and honey. Oviposition took place on cellucotton placed under the cage. Larvae were reared in petri dishes. A generation was completed in about 6 weeks. Eggs of the western corn rootworm held at room temperature for two weeks and at 40° F. for 40 days began hatching after 3 weeks exposure to 86° F., and continued to hatch for over three months. Prolonged refrigeration reduced the hatching period to 45 days. Eggs of this species do not require freezing temperatures for diapause breakage. Five types of plant or synthetic diets which were attractive to beetles were squash leaf, corn silk, corn borer artificial medium, casein-agar base diet with corn silk attractant, and pollen substitute.

2. Small Grain and Sorghum Insects. Tests conducted at West Lafayette, Ind., indicate a buildup of hessian fly (Race B) in the field. This race is capable of infesting W38 derivative wheats such as Monon, Dual, and Reed. With rapidly increasing acreage being planted to these resistant varieties, natural selection may favor the establishment of Race B populations. Two wheats, Lathrop and Knox 62, resistant to Race B, have recently been released.

Studies being conducted at West Lafayette on the inheritance of resistance of PI 94587, a Portuguese durum variety which has thus far remained immune to all known races of hessian fly, suggest that as many as 4 dominant resistance factors may be present in this variety. The transfer of the entire resistance gene complex from durum PI 94587 to common wheat types will be difficult but offers an approach to breeding for resistance to all currently known hessian fly races.

Radioisotope studies at West Lafayette have shown that hessian fly larvae consumed the most food during the fifth to seventh day of feeding and that larval growth was adversely affected by the isotope. Adult mutant forms (males without abdomens and females with growths on the thorax) emerged from wheat plants grown in P^{22} solution.

The reaction of barley plants and greenbug to several plastic materials used in cages was investigated at Stillwater, Okla. Cellulose acetate and vinyl cages killed young barley plants in less than 10 days and had an adverse effect on greenbug development and fecundity. Cellulose nitrate had no adverse effects on plants or insects.

The greenhouse greenbug biotype, which is capable of destroying wheat lines resistant to the normal field strain of greenbug, was found again in the greenhouse at Stillwater, Okla., for the third time in eight years. This strain, however, has not been found in the field.

Studies on the effect of temperature and host plants on fecundity of field and greenhouse biotypes of the greenbug at Stillwater, Okla., indicate that fecundity was not affected in the field biotype when reared on resistant and susceptible host plants at low temperatures, but at higher temperatures fecundity was greatly retarded on resistant plants. Fecundity of the greenhouse biotype when reared on resistant wheat (DS28A) was comparable to that of the field biotype when reared on susceptible plants (Ward barley) at all temperatures, indicating that DS28A wheat lacks resistance to the greenhouse biotype.

At Stillwater, Okla., the fall armyworm caused a yield reduction of 12% in late-planted sorghum, due to a decrease in the number and size of kernels in the infested heads. The corn earworm, southwestern corn borer, fall armyworm, and tobacco budworm have been successfully reared throughout their life cycles on artificial media for use in sorghum insect resistance studies.

At Manhattan, Kans., a study of the wheat curl mite in native or cultivated grasses indicated that grasses are not important in epidemic outbreaks of wheat streak mosaic. Grasses are probably helpful in maintaining endemic populations of the mite, but volunteer wheat is essential for epidemic outbreaks. Size and color of the wheat curl mite may be used as criteria for determining when populations are ready to disperse. Ninety-six percent of the larger (225-230 microns) darker (yellow) mites from the older, dry material became established when transferred to wheat seedlings, as compared with 62% of the smaller (218 microns) lighter colored mites from green, succulent wheat.

Research in Michigan indicated that the cereal leaf beetle has only one generation a year under field conditions. The adult diapause can be broken by artificial cold and under laboratory conditions all stages of the beetle can be made available for study throughout the year.

B. Insecticidal and Cultural Control

1. Corn Insects. Granular formulations which gave satisfactory control of first-brood European corn borer at Ankeny, Iowa, were diazinon, Sevin, endrin, Bayer 44646, Zectran, and Union Carbide 8305. Telodrin was most effective against second-brood borers. Zectran, Telodrin, and endrin in that order were the most effective when applied as a spray. The effectiveness of Sevin spray was increased by the addition of a spreader-sticker (Lovo 192). Systemic insecticides showing promise were American Cyanamid C.L. 47470 and C.L. 47031, reducing corn borer cavities in the stalks as much as 90% in some tests.

Studies conducted at Wooster, Ohio, growing resistant and susceptible single crosses in nutrient solutions, indicated that the level of borer establishment in both broods increased with an increase in phosphorus level. The resistant strain contained somewhat fewer larvae than the susceptible one, the difference being especially apparent in second brood infestation.

Of six insecticides evaluated for control of the corn earworm at Tifton, Ga., Bayer 41831 at 2 pounds per acre, Bayer 44646 at 1 pound, Bayer 47940 at 2 pounds, Zectran at 1 pound, and Telodrin at 1 pound, gave control equal to or better than that obtained with a 1-pound-per-acre application of DDT. Zinophos at 1 pound per acre and heptachlor at 1 pound gave poorer control.

In two experiments at two locations in Mississippi four to six applications of endrin at 0.5 pound per acre, or Sevin at 1.5 pounds per acre, significantly reduced plant girdling and breakage due to southwestern corn borer infestation. Control of the southwestern corn borer in late-planted corn resulted in significantly greater yields ranging from 8-19 bushels per acre. Fall cultural practices affected larval survival of the southwestern corn borer in Mississippi. Larval survival in undisturbed stalks the following spring was 64.3%; in uprooted stalks 4.4%; and in disked stalks 1.1%.

In Mississippi, aldrin at 1 pound per acre applied in a 6- to 8-inch band along the drill row, or at 2 pounds per acre applied broadcast at time of planting, gave better control of soil insects in cornfields the second year after treatment than the first. At Lincoln, Nebr., both phorate and diazinon gave good control of the resistant strain of the western corn rootworm.

2. Small Grain and Sorghum Insects. At Stillwater, Okla., Sevin at 1-1/2 pounds per acre was more effective against the corn earworm in sorghum heads (58% control) than Zectran at 1 pound (46%) and Bayer 37344 at 1 pound (31%). Sevin had the least effect on the beneficial predator, Orius sp. (13% mortality) followed by Zectran (67%) and Bayer 37344 (86%). Sorghum varieties exhibted differential burn reaction when treated with naled at 1 pound per acre, with 64% of the 72 entries showing injury. RS-610 and DeKalb E56a, the varieties used most commonly in previous insecticide spray tests for sorghum insect control, showed little or no burning.

Of seven materials tests against the army cutworm on wheat in Oklahoma, endosulfan (92%), endrin (89%), and Bayer 25141 (81%) gave the best control, although the Bayer compound resulted in some phytotoxic effect when applied to Triumph wheat at 1 pound per acre. In tests conducted at Stillwater against the corn flea beetle dieldrin (95%) and Telodrin (95%) at 1/2 pound, toxaphene (91%) at 2 pounds, and DDT

(94%) at 1-1/2 pounds, gave the most effective control.

In Michigan Sevin at 3/4 to 1 pound per acre gave better control of the cereal leaf beetle on oats than malathion at 1 pound per acre.

Insecticides as foliage, furrow, and seed applications were tested for wheat stem sawfly control at Bozeman, Mont. Heptachlor and heptachlor epoxide applied as furrow and seed treatments at time of seeding gave the best control. Applications were made with a commercial type fertilizer attachment on a press drill or with a single-row belt seeder. Both were effective. Rate of seeding along the margin of wheat strips as a means of decreasing wheat stem sawfly cutting was also studied at Bozeman. The heavier seedings had a lower percentage of cutting in one test but not in another. examination of wheat inside the field next to the heavily seeded rows showed no reduction in amount of sawfly cutting, regardless of seeding rates.

Under low levels of insect and mite populations on wheat subjected to stubble mulch and clean cultivation tillage practices, more army cutworms, brown wheat mites, white grubs, and false wireworms were found in the stubble mulch than in the clean cultivation plots. Populations of the greenbug, apple grain aphid, and English grain aphid were about the same in both tillage practices.

C. Insecticide Residue Determinations

1. Residues on Corn. Corn treated with 1 and 2 pounds of diazinon in granular formulation for European corn borer control, at Ankeny, Iowa, had residues of 8.9 and 23.1 p.p.m., respectively, 2 days after treatment. In 16 days these residues were reduced to 0.1 p.p.m. and 0.4 p.p.m. No diazinon residue could be detected 48 days after application.

Sevin applied as a spray to corn four times, at 4-day intervals, produced residues on the husks 1 day after the last treatment of 38.3 p.p.m. when applied alone, 38.1 p.p.m. when applied with "Plyac" sticker, and 33.2 p.p.m. when applied with "Lovo" sticker. Samples of husks and cobs collected 7 days after the last treatment contained 8.0, 11.4, and 10.4 p.p.m. of Sevin from treatments of Sevin alone, Sevin plus Plyac, and Sevin plus Lovo, respectively. Subsequent fermentation of the corn did not result in an appreciable loss of Sevin.

1-Bromochlordene granules applied to corn plants for control of the first brood of European corn borer at Ankeny, Iowa, at 1 pound per acre left residues of 1.93 p.p.m. and 0.22 p.p.m., 2 and 16 days after application, respectively. The residue of 0.22 p.p.m. remained for 48 days without further decrease.

At Tifton, Ga., sweet corn treated with varying rates of Telodrin was analyzed for residues on different dates after application. Residues on leaf and stalk samples taken immediately after treatment ranged from 8.4 p.p.m. on plots treated with 2 pounds per acre down to 1.9 p.p.m. on plots treated with 0.5 pound per acre. Immediately after treatment residues on the husks ranged from 1.8 to 2.0 p.p.m. Only the 2-pound-per-acre level showed any residue (0.01 p.p.m.) on kernels and cob. Telodrin residues declined rapidly 24 hours after application. No residue was detected on the kernels and cob at any treatment level on the day of application. The residue deposit on leaf and stalk was 8.4 p.p.m., immediately after treatment; after 21 days it was 0.7 p.p.m.

In a study of the persistence of endosulfan on corn plants at Tifton, Ga., 1 pound of endosulfan per acre was applied as an emulsifiable concentrate spray. The initial deposit was about 16 p.p.m., which decreased to about 0.2 p.p.m. after 3 weeks in the field.

D. Biological Control

1. Corn Insects. At Ankeny, Iowa, one application of a granular formulation of Bacillus thuringiensis gave as good control of first- and second-brood European corn borers on field corn as did DDT or endrin, two insecticides recommended for borer control. Control with other formulations was unsatisfactory. A spreader-sticker did not enhance borer control of spray formulations of B. thuringiensis used in multiple applications on sweet corn. Beauveria bassinana and Metarrhizium anisopliae were the most pathogenic of the fungi isolated from dead corn insects. Aspergillus parasiticus and Fusarium neoceras, while less pathogenic, were much more common in the wild populations. Other fungi isolated but less virulent and common were A. niger, A. ustus, Mycodirma clayi, paecilomyces varioti, Penicillium cyclopium, P. decumbens, P. puberlum, Rhizopus stolonifer, and Scopulariopsis brevicaulis, some of which have not previously been reported from insects.

At Wooster, Ohio, predators eliminated approximately one-third of the first-brood and one-fourth of the second-brood borers. Microplitis croceipes was the most important parasite of corn earworm larvae feeding in whorl stage corn at Tifton, Ga. A tachinid parasite of Heliothis armigera, imported from India, successfully oviposited and developed in the corn earworm. Development of this parasite was poor in the armyworm.

Investigations involving larvae, pupae, and adults of Heliothis zea and Spodoptera frugiperda at Tifton, Ga., revealed the presence of a variety of pathological conditions in the absence of etiological agents. Heavy deposits of crystals and crystalloids were seen in the adipose tissue, pericardial cell, and muscle tissue in both hosts.

Hypertrophy and granulation changes were observed in a nuclei of the affected tissues and in their vicinity in a manner suggesting insipient stages of pathological changes. Abnormal tissue formations frequently denoted by intense melanin deposits were diagnosed, especially in pupae. In adults similar symptoms were accompanied by lack of development of ovaria and occasionally anomalous feeding behavior (bloating).

Aldrin, dieldrin, heptachlor, and diazinon had no adverse effect on soil bacteria or nematodes at Brookings, S. Dak., when applied at concentrations up to 1000 times normal field dosages.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. Female fall armyworm moths laid sterile eggs after being individually fed 62.5 micrograms of tepa per moth in a 10% sugar solution. Male moths were sterilized when fed 31.2 micrograms of tepa per moth. No apparent reduction in mating was observed in female fall armyworm moths which were fed 62.5, 125, 250, or 500 micrograms of tepa per insect. However, the frequency of matings per female was reduced. Male fall armyworm moths were sterilized when fed 31.2 and 62.5 micrograms of tepa per moth but were able to mate as frequently as untreated moths.

Only sterile eggs were produced from matings of female and male fall armyworm moths fed on a 1% honey solution which contained 1 mg. of apholate per ml. Apholate reduced egg production by fall armyworm moths which emerged from pupae dipped in water solutions containing 1 mg. of apholate per ml. However, the eggs deposited by these moths were viable. Unmated fall armyworm moths, 3, 4, 5, and 6 days old were fed for 24 hours on a 10% honey solution containing 0.5 mg. of apholate per ml. None of the eggs produced after mating were viable. On the other hand viable eggs were produced by 1- and 2-day-old moths fed the solution and by moths fed immediately after emergence. Continuous exposure of fall armyworm moths to a solution of 1 mg. of apholate to 1 ml. of honey, practically eliminated egg laying. The frequency of mating was reduced by 64%.

Progress is being made in the field of attractants. At State College, Miss., an extract from frozen vapor collected from a freeze-dry apparatus in the lyophlization of fresh corn silks proved to be an attractant to corn earworm larvae. However, it had no effect on the adults. At Brookings, S. Dak., a feeding arrestant was extracted from corn leaves which when added to cellulose-cotton caused northern and western corn rootworm beetles to feed on the material. At Ankeny, Iowa, an ether extract of tips of abdomens of mating pairs of corn borer moths was an effective sex (male) attractant in small cage laboratory studies.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. Sticky-board surfaces covered with an adhesive, "Stickem", on cylindrical drums held on vertical poles at 3-, 6-, 9-, and 12-foot levels, effectively trapped adults of the northern corn rootworm and provided evidence that flight of most beetles in growing corn in late August occurred below the 6-foot level. The trap appears promising for the detection and measurement of adult populations of corn rootworms.

Agricultural engineers and entomologists at Tifton, Ga., found that plants dusted with an electrostatic duster, producing both positively and negatively charged particles, had about 57% and 36%, respectively greater residues than plants dusted with uncharged particles, even 48 hours after application. The positively charged dusts in general produced slightly higher residues than the negatively charged dusts. These researchers also determined that superior spray coverage and corn earworm control could be obtained when sprays were applied at 100 p.s.i. with fan type nozzles placed 90° to the plant. Methylene blue was a satisfactory dye for use in a study of spray residue deposit.

At Brookings, S. Dak., a method of extraction of rootworm eggs from soil was devised, utilizing a flotation technique. A soil sample is placed in a container of concentrated sugar solution and agitated briefly by a magnetic stirrer. The debris floating on the surface larger than rootworm eggs is removed with a screen. The remaining debris is washed onto filter paper in a bücher funnel, and the excess water removed. The filter paper is then examined under a dissection microscope for the eggs. All stages of the rootworm float readily in concentrated sugar solution without any apparent ill effects. Use of a ratio of 1 part soil sample to 4 parts of a 2.6 molar sugar solution, with an agitation time of 3 minutes and a flotation time of 5 minutes, provides a suitable means for recovering 85% of the rootworm eggs in a sample of sandy loam soil.

2. Small Grain Insects. Under conditions prevailing in South Dakota during the spring of 1963, yellow pan traps were nearly useless for detection of grain aphid flight activity. Grain aphids were repeatedly taken in wind traps during April and May while yellow traps were apparently unattractive. Beginning early in June, yellow pans began to yield specimens of the grain aphid.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. One-hundred and forty-three inbred lines of corn submitted from State and Federal agencies associated with the Southern Corn Improvement Conference area were evaluated at Ankeny, Iowa, for first-brood European corn borer resistance. Fifteen percent of the

entries were rated as highly resistant, 60% were intermediate, and 25% were susceptible.

Studies conducted at Ankeny, Iowa, on factors affecting stalk lodging (and harvest) as measured by crushing strength indicated that as the mean corn borer infestation, stand, and nitrogen application increased, the crushing strength decreased.

Progress in the development of corn borer resistant hybrids during the past decade was studied at Ankeny, Iowa, by comparing a group of old and new hybrids. On the basis of differences in yield between the treated and infested split plots, three hybrids extensively grown 10 years ago (Ia.4297, Ia.4417, and US.13) lost an average of 13.8 bushels per acre as a result of corn borer infestation. Five of the newer hybrids (Ia.5036, Ia.5087, Ia.5063, AES.514, and AES.704) lost an average of only 4.6 bushels per acre. Stalk breakages for the older and newer hybrids were 15.2 and 2.0%, respectively.

At Ankeny the Iowa inbred B52 was the most resistant line to second brood European corn borer. Released inbreds R101, R181, B51 and an experimental WF9 recovery also exhibited a very satisfactory degree of resistance. Lines classified as having intermediate resistance were B14, B53, B54, B55, B57, and B50.

At Wooster, Ohio, inbred lines of dent corn, submitted by corn breeders from the Northern States of the North Central Region were evaluated for corn borer resistant germ plasm. Many inbred lines from the Michigan Agricultural Experiment Station, some reciprocal recurrent selections out of double crosses, and some derivatives of crosses between susceptible and resistant lines and brachytic and prolific segregates, had a good degree of resistance. Eighteen hybrids, primarily experimental double crosses, also had a good level of resistance.

At State College, Miss., quality or quantity of 20 protein amino acids was not associated with resistance in the resistant dent corn cross (F6 x Mp426), an intermediate dent corn cross (Mp426 x Mp319), and a susceptible dent corn cross (Mp317 x Mp319). The concentration of non-protein amino acid was associated with resistance, being lower in the resistant cross, and higher in the susceptible cross.

Experimental dent corn hybrids and commercial hybrids, from Mississippi, Louisiana, and Texas showing promising corn earworm resistance, are Dixie 18, La. 521, Coker 67, Delta 8812, Keystone 257, Coker 811, Asgrow 500, Texas Experimental 6001, Ala. 8456, and Ala. 8471. Yellow inbreds with a high degree of resistance to the corn earworm in other experiments were as follows: Mp440, LSc 64, L699, and the Texas inbreds 529, 601, and 325.

At State College, Miss., a two-inch husk extension over the tip of the corn ear was sufficient to give protection from the corn earworm. Husk extensions over 2 inches offered no additional protection.

Hybrids that have shown a high degree of resistance to the southwestern corn borer in Mississippi include Pioneer 8218, Funk G 795W, Delta 9907, and the single crosses Mp202 x Mp428 and Mp202 x Mp210.

In Mississippi, it was determined that rice weevil infestation in a cornfield was associated with insect migration and source of infestation. Some of the more resistant rice weevil hybrids which have been tested are: Miss. 6133, DeKalb 1225, Keystone 257, Dixie 82, McNair 444B, Coker 71, Pfister 750, DeKalb 1240, Dixie 18, Pioneer 309B, Pfister 653W, and Dixie 55.

At Tifton, Ga., bioassay of extractions of freshly harvested plant material have indicated that corn silks and leaf tissue vary in susceptibility and resistance to fall armyworm and corn earworm feeding. Inbreds with foliage resistance against the fall armyworm do not necessarily have resistance against the corn earworm.

A technique has been developed at Ankeny, Iowa, for determining quantitatively the presence of 6-methoxybenzoxazolinone in corn inbreds. This procedure involves the use of C^{14} -labeled 6-methoxybenzoxazolinone. With this technique a near-perfect correlation between 6-methoxybenzoxazolinone and field evaluations of resistance of corn inbreds to the European corn borer was obtained.

2. Small Grain and Sorghum Insects. In field tests conducted at Stillwater, Okla., five greenbug resistant F_8 wheat selections yielded about 28 bushels per acre while the susceptible check, Ponca, was completely destroyed. Infested resistant crosses showed a loss of 0 to 4 bushels per acre over non-infested resistant crosses, due to greenbug feeding. Of 19 barley lines infested by the greenhouse (virulent) greenbug biotype, 17 appeared to have a high degree of resistance. Notable among these were Kearney, C.I. 7580, Dobaker C.I. 5238, Omugi C.I. 5144, and Chase C.I. 9581. Three rye selections from Argentina designated as AR-1, AR-3, and AR-4, showed almost complete immunity to this greenbug strain. No wheat selections have been found with any degree of resistance to this biotype.

Cooperative research with wheat breeders in several States was continued to develop hessian fly-resistant wheats under leadership of the West Lafayette, Ind., station. Over 15,000 lines, hybrids, varieties, and selections were evaluated. Seventeen fly-resistant varieties are now recommended and grown in the United States. Fly-resistant wheats, Reed (C1 13513) and Knox (C1 13701), which obtain their resistance from W38 (H_3) and P1 94587 (H_6), respectively, were

released by the Purdue University Experiment Station in 1962. It is estimated that 4-1/2 million acres of hessian fly-resistant wheat were grown in 1961-62. Progress has been made in the development of wheats which have combinations of one or more types of resistance, namely, Kawvale, Marguillo, W38, PI 94587, and Ribiero. Multiple resistant type wheats are needed to prevent or slow down the development of new hessian fly races in the field.

Monosomic analysis, using Chinese monosomic plants, indicated that chromosome 5A(IX) is responsible for the single gene resistance of PI 94587 derivatives.

Forty-five selections from the barley backcross Besert x $\frac{4}{3}$ Decatur obtained from Beltsville, Md., were tested at West Lafayette, Ind., for resistance to Race A hessian fly. These backcross lines have continuously shown a high type of resistance. One hundred and sixty-one Purdue winter barleys having fly-resistant parents were also tested to Race A. Seventy-one promising selections were saved for further selection or crossing in Uniform Wheat Nurseries.

Several hundred selections of wheat, oats, and barley were rated for for resistance to the cereal leaf beetle. Some differences were observed in them and one selection of wheat (Triticum persicom var. fulginosum) was almost immune. There appeared to be a positive correlation between resistance and the amount of pubescence on the leaves.

Studies on wheat stem sawfly resistance were conducted in cooperation with wheat breeders of the Cereal Crops Research Branch, Crops Research Division, entomologists and plant breeders of the Montana and North Dakota Experiment Stations, and the Science Service Laboratories of the Canada Department of Agriculture.

Tests conducted at Minot, N. Dak., on varieties from the World Collection have revealed no new sources of resistance to the wheat stem sawfly. Several thousand F_3 and F_6 hybrid selections from the North Dakota breeding program were evaluated and reselected on the basis of agronomic qualifications and reaction to sawfly and rust. Selection 57-134, a very promising product of the North Dakota program, was disqualified as a potential sawfly-resistant variety by its poor agronomic performance. Selection 60-54, from the cross 51-3549 x II-50-17, is now considered to be the most promising sawfly-resistant selection.

In the International Sawfly Nurseries, several varieties and advanced hybrid selections from the breeding program of Canada, Montana, and North Dakota, exhibited a degree of sawfly resistance equal or superior to that of the resistant Rescue check. Some solid-stemmed

Rescue-N1315 x 1315 x Golden Ball hybrids (possessing a type of stem solidness different from that of Rescue) and Thatcher x Rescue hybrids, have shown particular promise.

Preliminary studies at Brookings, S. Dak., indicate that the solid stem sawfly-resistant wheat Rescue developed hollow stems when grown under a short length day at a moderately high temperature. The normal solid stems developed when the wheat was grown in growth chambers programmed for an 18-hour day and moderate temperature.

At Tifton, Ga., 59 of 192 grain sorghum lines screened for resistance to the grain sorghum midge exhibited resistance in varying degrees, and at Stillwater, Okla., differential reaction to corn leaf aphid was observed among sorghum varieties, with DeKalb, Plainswan, and DeKalb Shorty 50 having the lowest populations of the insect.

H. Insect Vectors of Diseases

1. Corn Insects. A plant virus believed to be previously unknown was studied for comparison with other related viruses. The virus, which has been designated Pumpkin Mosaic Virus, or PMV, was effectively transmitted by the striped cucumber beetle, northern corn rootworm, southern corn rootworm, western corn rootworm, and a grasshopper, Melanoplus differentialis. Possible transmission was also observed by three aphid species.

Root-rotting fungi have been associated with corn rootworm feeding injury. They have been isolated from rootworms and from rot-damaged roots. In pathogenicity tests conducted in the greenhouse on representatives of fungi isolated, none were highly pathogenic under the conditions of test but most of the isolates did produce some degree of rotting.

In Rehovoth, Israel, (P. L. 480 project, A10-ENT-5) the planthopper, Calligypona marginata, was discovered to be the vector of the rough dwarf virus disease of corn. This disease has caused serious damage to corn in countries bordering the Mediterranean Sea but does not occur in the United States.

2. Wheat Insects. The wheat curl mite, vector of the wheat streak mosaic disease, was not a problem in 1963. Little mosaic virus was present on volunteer wheat and the mite vectors present were late in dispersing, so that the mosaic that was transmitted to the wheat crop caused little damage.

In Helsinki, Finland, (P. L. 480 project, E8-ENT-1) it was established that Calligypona pellucida females caused toxic injury to hosts, the amount of injury and abundance of leafhoppers being positively

correlated. It was also established that C. sordidula causes a kind of damage to oats which resembles a virus type of disease. Of the C. pellucida vector females proved considerable more effective in spreading the virus than males.

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AREA NO. 8. RICE INSECTS

Problem: A number of insects including leafhoppers, the rice stink bug, and rice water weevil, seriously damage rice in the several rice-growing areas of the United States. More information is needed on safe, effective chemical-control methods, and on cultural-control methods, to destroy these pests and reduce the damage they cause. Additional emphasis should be given to new approaches to control rice insects. Rice varieties need to be evaluated for resistance to major rice insects. The discovery of hoja blanca, a virus disease of rice, and its insect vector, a planthopper, in the commercial rice-growing area of Louisiana, has greatly intensified the need for more information on the biology, ecology, and control of the vector, and on its relation to transmission of the virus.

USDA PROGRAM

The Department's program on rice insects involves entomologists, agronomists, plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Agricultural Experiment Station. Some of the lines of work have been underway for only a short period of time.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.2 to insecticide residue determinations on rice; 0.2 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; 1.0 to insect vectors of hoja blanca and 0.2 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology and Nutrition

Rice stink bugs (Oebalus pugnax) were reared from the egg to adult on rice seedlings in the laboratory at Baton Rouge, La. Mating was observed but no eggs were laid, indicating that while rice seedlings are adequate for maintenance and growth of the stink bug, they are apparently nutritionally inadequate for egg production.

At Baton Rouge, studies were made of external morphological characters that might be used for determining the sex of rice water weevils

(Lissorhoptrus oryzophilus). The most useful character found was the curvature of sternites 1 and 2. These sternites in the male are concave at the midline; in the female they are convex. The fifth sternite has a raised area that covers more than half the sternite in the female but less than half in the male; the posterior border is curved in the female and straight in the male.

The rice delphacid, Sogata orizicola, can live as long as 13 days without feeding on the rice plant if supplied with water. At a temperature of 80° F. and a relative humidity of 100%, the insects lived less than 10 hours; at 60° F. all insects died in 20 hours. Brachypterous (short wing) females lived longer than alates (winged), and females lived longer than males in all tests.

B. Insecticidal and Cultural Control

In field studies with insecticides at Baton Rouge, La., Sevin at 0.8 pound per acre, methyl parathion at 0.25 pound, and Bidrin at 0.25 pound, gave good control of the rice stink bug. Methyl parathion at 0.125 pound per acre also gave adequate control in most tests.

At Baton Rouge, seed treatment with 4 ounces of aldrin per 100 pounds of seed gave good control of rice water weevil. In field experiments, no damage to seed germination was found with application rates up to 1 pound per 100 pounds of seed. The fungicide, Panogen, caused a decrease in percentage germination when applied at 1 ounce per bushel of seed. There was also an interaction of fungicide and insecticide at higher rates of application. At rates of 1 pound of aldrin per 100 pounds of seed and 1 ounce of Panogen per bushel, germination was reduced by 70%. Panogen alone at this rate reduced germination only 26% and aldrin alone was not phytotoxic.

Insecticides were tested in the greenhouse at Baton Rouge for control of the rice delphacid, Sogata orizicola. Menazon 70% wettable powder applied as a seed treatment at a rate equivalent to 1 pound per 100 pounds of seed gave 100% control at 8 days after planting, 84% after 14 days, and 17% after 22 days. There was apparently no reduction in seed germination. This is the only seed treatment tested that appears promising for leafhopper control. Isolan applied as a spray at a rate of 1/2 pound per acre and Dimetalin at a rate of 1 pound per acre gave good control up to 20 days after treatment. Isolan applied as a flush treatment to pots of rice in the greenhouse at a rate of 1/2 pound per acre and Bidrin at a rate of 2 pounds per acre gave good control of the insects for 14 days, and partial control up to 21 days following application. Phorate and Di-syston applied as granules at a rate of 2 pounds of insecticide, and Dimetalin at 1 pound, per acre gave good control of the rice delphacid in the greenhouse for 30 days. Bayer 25141 in the initial phase of testing also showed promise as an insecticide for control of leafhoppers.

Insecticidal control of the green rice leafhopper, Draeculacephala portola, was also studied. Phorate and Di-syston applied at a rate of 2 and 4 pounds per acre at the first flood or 2 pounds per acre at the second flood, gave good control of the leafhopper. No differences in yields were associated with the different treatments.

C. Insecticide Residue Determinations

At Baton Rouge, La., in a cooperative study with Pesticide Chemicals Research Branch, rice seed treated with aldrin lost about 40% of the insecticide during presprouting operation, probably in the water used to soak the rice grains. This might explain why fish and crayfish are somtimes killed in streams and ponds used to soak rice seed prior to planting.

Analysis made of duck which had been fed 50 mg. of technical aldrin in gelatin capsules, and killed 48 hours later, showed that the oil gland had 120-230 p.p.m. of dieldrin, the body fat 60-280 p.p.m., and skin fat 7-132 p.p.m. The remaining tissues had less than 30 p.p.m. of dieldrin.

D. Varietal Evaluation for Insect Resistance

Greenhouse studies were made at Baton Rouge, La., on preferential egg deposition by Sogata orizicola on various rice varieties. The variety, Dina, was less acceptable for oviposition than Bluebonnet 50, Gulf Rose, or BG-79.

E. Insect Vectors of Disease

The insect vector of hoja blanca, the rice delphacid, Sogata orizicola, was found on 34 properties in 7 parishes of south Louisiana during 1962. All of the infested fields were treated with insecticides, phorate, Phosdrin, or a DDT-malathion mixture by the Plant Pest Control Division. Subsequent surveys for insect vectors at the end of rice harvest in these fields were negative. No hoja blanca was found. A single specimen of Sogata was recovered in rice on Kramer Island, Palm Beach County, Fla., on June 18, 1963.

A new method was developed for screening insect transmitters for a greenhouse colony, using plants 4-7 days old (about 3-leaf stage). Symptoms of hoja blanca develop in infested plants in 4-11 days following exposure to insects. Techniques used previously required 1-5 weeks for symptom development. With the new technique nymphs are used instead of adults, permitting controlled mating of known transmitters. This technique had made possible the selection of laboratory populations with 80-95% of the individuals capable of transmitting the hoja blanca virus.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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AREA NO. 9. COTTON INSECTS

Problem. Insect control continues to be one of the major cost factors in the production of the cotton crop. Insecticides must be utilized each year throughout most of the Cotton Belt for profitable production. Although many highly effective insecticides have been made available, the development of resistance to certain insecticides in 20 cotton insect pests emphasizes the need for basic information on ways to solve or avoid the problem and to develop other methods of control that are more effective, economical and desirable. There are some hazards involved in the use of current insecticides because of possible resulting residues in food and feed products made from cottonseed and because of drift to vegetable and fruit crops and to forage crops consumed by animals. An imbalance of beneficial insect populations and hazards to fish and wildlife may result from insecticides now employed on cotton. Research on sterile male techniques, attractants, feeding stimulants, repellents, cotton varieties resistant to insects, postseason applications of insecticides to prevent diapause and winter survival, biological control agents, safer insecticides and more effective ways of applying them, chemically induced plant resistance to insect attack, and chemical regulation of the fruiting period of the cotton plant, are among new approaches that need attention in efforts to improve methods of control. Effective methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. An outbreak of the pink bollworm in Arizona has recently posed a threat to cotton production in California. The boll weevil is gradually extending its range westward and may be adapting itself to an arid climate. Infestations in northern Sonora, Mexico, could endanger cotton production in Arizona and California where the pest does not now occur. One of the basic difficulties in cotton insect control is the lack of knowledge of factors influencing insect abundance which can serve as a basis for advising growers when control measures for the various pests will or will not be required.

USDA Program

The Department has a continuing long-term program involving entomologists, insect and plant physiologists, insect pathologists, insect and plant geneticists, chemists, biochemists, agricultural engineers, soil scientists, and economists engaged in basic studies and the application of known principles to the solution of cotton growers' insect problems.

Basic biological, physiological and nutritional studies involving (1) ecological factors affecting abundance and distribution of cotton insects in the field and laboratory are conducted at Tucson, Ariz., Tallulah, La., State College and Stoneville, Miss., Florence, S. C., and Brownsville and Waco, Tex.; (2) fundamental research in determining physiological processes, biochemical requirements in the normal metabolism of the boll weevil, bollworm, pink bollworm and cabbage looper are conducted at Baton Rouge, La., State College, Miss., Florence, S. C., and College Station and Brownsville, Tex.; and (3) research on mode of action and fate of various chemicals in the insect, mechanisms by which insects develop resistance to insecticides and how such mechanisms may be rendered ineffective is conducted at Baton Rouge, La. The above research is cooperative with the Agricultural Experiment Stations in the respective States. The ARS Plant Pest Control Division cooperates in studies under item (1). Insecticidal and cultural control studies pertaining to (1) the evaluation in the laboratory of candidate chemicals for cotton insect control and field evaluation of those showing promise are conducted at Tucson and Tempe, Ariz., Tallulah, La., State College and Stoneville, Miss., Florence, S. C., and Brownsville, College Station, and Waco, Tex.; (2) research to develop safe, economical and effective schedules of insecticide applications for guidance of growers in meeting the wide variety of insect problems on cotton is underway at Tucson, Tallulah, Stoneville, Florence, Brownsville and Waco; and (3) the effects of such cultural practices as stalk destruction, defoliation, irrigation, time of planting and soil improvement on cotton insect populations are being investigated at Brownsville and Waco, Tex. The above research is cooperative with the Agricultural Experiment Stations in the respective States. Industry cooperates extensively in this research and supplies most of the candidate chemicals. Research on biological control agents involving (1) insect pathogens for control of the boll weevil, pink bollworm, bollworm and cabbage looper and (2) beneficial insects for the control of several cotton insects is conducted at Brownsville, Tex., Tucson, Ariz., State College and Stoneville, Miss., and Florence, S. C., in cooperation with the Agricultural Experiment Stations in these States. Fundamental research to discover and develop new methods and approaches to control cotton insects involves (1) sterile male techniques, attractants, feeding stimulants and repellents; (2) effects on insect development resulting from chemical manipulation of the fruiting behavior of the cotton plant by plant scientists; (3) chemical induction of plant immunity to insects into the plants; and (4) the utilization of radiant energy. This work is conducted at Tallulah, La., State College and Stoneville, Miss., Florence, S. C., Brownsville and College Station, Tex., in cooperation with the Agricultural Experiment Stations in these States, and with ARS Crops Research and Agricultural Engineering Research

Divisions. Evaluation of equipment for insect control and detection pertaining to (1) insecticide application equipment, stalk shredders, and gin and oil mill equipment for insect control and (2) light traps for determining the presence and abundance of certain cotton insects, are made at State College and Stoneville, Miss., and Brownsville and Waco, Tex. This work is in cooperation with the Agricultural Experiment Stations in these States and with the ARS Agricultural Engineering Research and Plant Pest Control Divisions. Varietal evaluation for insect resistance is conducted at Tucson, Ariz., State College, Miss., and Brownsville, Tex., in cooperation with the Agricultural Experiment Stations in these States and the ARS Crops Research Division.

The Federal scientific effort devoted to cotton insects research totals 61 professional man years. Of this number, 22 are devoted to basic biology, physiology and nutrition; 18.4 to insecticidal and cultural control; 5.2 to biological control; 8.3 to insect sterility, attractants and other new approaches to control; 1.3 to evaluation of equipment for detection and control; 2.7 to varietal evaluation for insect resistance; and 3.1 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Boll Weevil. Boll weevil survival was lower than usual in all areas in the spring of 1963. Spring woods trash examinations for hibernating boll weevils were made in Central Texas, Northeast Louisiana, Delta and Hill sections of Mississippi and 4 areas in the Carolinas. Comparative survival since 1959 in the various areas was as follows:

	Weevils Per Acre				
Area	1959	1960	1961	1962	1963
Central Texas		2065	1516	1361	432
Northeast Louisiana	2246	4754	2193	2233	121
Mississippi	464	821	1246	1132	13
South Central, S.C.	699	861	376	1667	914
Coastal Plains, S.C. & N.C.	1963	1049	1129	3654	1560
Piedmont, S.C. and N.C.	242	590	1558	2823	350
North Central, N.C.	817	377	430	968	161

Survival percentage of 5.7% at Florence, S. C. was lower than in any year since 1943. Low survivals also occurred in 1961 and 1958 with percentages of 6.5 and 6.9, respectively. In Madison Parish, La., where similar records have been made for 27 years, the survival was 10%. Survival was lower only in 2 previous years, 1937 and 1940, when it was 2 and 8%, respectively.

In a replicated study to determine optimum boll weevil hibernation conditions at Florence, S.C., a significantly greater percentage of weevils survived in the 1-inch depth of woods trash of normal moisture content and in the 3-inch depth of dry trash than in the 3-, 5- and 7-inch normal and 3-inch wet treatments. Considerable intra-treatment and little inter-treatment weevil movement occurred in the experiment.

Emergence of overwintered boll weevils from hibernation sites continued through July at Tallulah, La. Diapausing boll weevils were collected on trap cotton plantings through July 31, 1962, in a field which had been planted to cotton in 1961.

Boll weevils hibernated in ground trash in northern Sonora Mexico in 1963. Examinations made during the latter half of January along the edges of 25 untreated and 39 fall-treated cottonfields showed population averages of 825 and 97 weevils per acre, respectively. Boll inspections during the same time showed an average of 1,815 weevils in bolls on stalks in the treated fields and 4,010 per acre in untreated fields.

Ground trash examinations in the same locations in April showed an average of 142 weevils in treated and 174 per acre in untreated fields for survival percentages of 146 and 21, respectively. The survival figures may not be too meaningful because trash bordering cottonfields was much drier in April than in January and overwintered weevils probably had moved to very restricted areas of moist trash along irrigation ditches. Most of the weevils were found in such locations. However, the results show that boll weevils do survive in ground trash from one crop year to the next in the area. Very few bolls were available for inspection in April. Sixteen live weevils were found in 850 bolls collected in 3 fields from standing stalks or those which had been cut and placed in piles. These results showed that boll weevils survived from one crop year to the next in bolls on standing stalks. Results of limited hibernation studies in cages at Caborca, and Magdalena, Sonora, Mexico, from November, 1962 to May 1963, also showed that weevils survived in ground trash and in surface or buried bolls from one crop season to the next. Thurberia weevils in cages during the same period at Tucson, Ariz., survived well in bolls on the soil surface but those removed from bolls and installed in ground

trash emerged from it in January, February, and March, and none were recovered when the trash was inspected in May.

In field inspections made by personnel of the Tucson, Ariz., laboratory five boll weevils were found when 1090 cotton plants were inspected in the vicinity of Magdalena, Sonora, Mexico, on June 12, 1963. On June 19 an infestation of 21% punctured squares was found in a field 6 miles northeast of Altar.

In studies at Florence, S. C., seven times as many overwintered boll weevils were collected on 9 groups of 10 fruiting cotton plants placed in the middle of a field than on nine 3 x 5 foot flight screens placed along the edge of a hibernation site bordering the field. This technique may provide a better index of numbers of boll weevils emerging from hibernation sites than flight screens. Nine overwintered boll weevils were collected on 4 groups of 10 squaring cotton plants placed in an open field. Only one weevil was collected on 4 similar groups placed in the middle of an 8-foot alley between grain plots. This indicates that the grain had a masking effect on the attractiveness of the plants to the weevils.

In a study of weevil flight habits in entering and leaving cottonfields at Florence, S. C. in 1962, collections on elevated flight screens showed that most flights into the field from hibernation sites in April, May, June, and July, were at altitudes of 7.5 to 10 feet, with most of them occurring in June. Most flights out of the field during the migration period in August and September were at altitudes above 30 feet.

Food and temperature appeared to be primary factors which induce diapause in adult boll weevils in studies at Stoneville, Miss. Diapause responses of adult boll weevils to type of food, temperature, and photoperiod were observed in controlled environmental chambers. Forty to 50% of media-reared weevils fed on plants bearing only bolls attained diapause under constant temperatures of 70° and 80° F., with photoperiods of 10, 12, 14 and 15½ hours. Under the same temperatures and photoperiods, 0 to 15% of weevils fed on squaring plants attained diapause. However, when the night temperature was maintained at 50° F. and the daytime temperature at 70° F. under a 10-hour photoperiod, the percentages entering diapause were the same for those fed on squaring plants as for those fed on plants bearing only bolls.

Limited data at State College, Miss., indicated that quantity of food consumed may be a primary factor in diapause induction of the boll weevil. Photoperiod and temperature may be secondary because they influence the amount of food consumed. Low temperatures and short photoperiods together appear to exert

more influence than either of the conditions alone.

Quantity of food available in the adult stage as well as an 11-hour photoperiod in larval and pupal stages appeared to induce diapause in the boll weevil in laboratory studies at Stoneville, Miss. When adult food was limited to 1 square per 10 weevils per day at 80° F., diapause was induced when the larval and pupal stages had been exposed to either continuous light or an 11-hour photoperiod at 80° F. However, when the quantity of food was increased to 1 square per 5 weevils per day, only those exposed to the 11-hour photoperiod in the larval and pupal stages attained diapause in significant numbers.

Boll weevils required several weeks to attain firm diapause in the laboratory at Stoneville, Miss. Moisture and fat content were used as measures of the intensity of diapause in a series of studies conducted under controlled environmental conditions. Boll-fed weevils under conditions of 80° F. during the day and 50° during the night with a 12-hour photoperiod attained the highest fat and lowest moisture content after two weeks. Square-fed weevils at 70° F. during daytime and 50° during nighttime temperatures with a photoperiod of 10 hours required 4 weeks to develop maximum fat and minimum moisture content.

Studies at Baton Rouge, La. indicated photoperiodic control of diapause in the boll weevil. An 11-hour photoperiod during the early immature stages resulted in a high incidence of diapause in weevils from Louisiana. A 13-hour photoperiod inhibited diapause. The photoperiodic response of thurberia weevils from Arizona was less pronounced. One culture of weevils originating from the coastal regions of Mexico showed a very low tendency to enter diapause under all conditions.

In studies at the Boll Weevil Research Laboratory, State College, Miss. the numbers of mature eggs in female boll weevils were the best criteria for quantitative estimate of decreasing reproductivity with onset of diapause. The number of mature eggs per female decreased during the period from mid-August to mid November in specimens from State College, Miss., Presidio, Texas, and Northern Sonora, Mexico. Results showed that the percentage of diapause in populations across the country increases rapidly after about August 15 but generally only 20 to 30% of the adults in the field are in firm diapause during peak periods.

Studies at the Boll Weevil Research Laboratory showed that the home range of the boll weevil can be defined. A quantitative study of boll weevil movements in a 1/3 acre cotton field showed that the weevil does not wander at random through the

field but tends to remain in a limited area. Total measurements of movements as calculated on coordinate axes were used as a method for quantitating home range. Even though males were more frequently recaptured over longer periods than females, average patterns of movement were similar. Both sexes tended to move farther along cotton rows than across rows.

Damage to cotton squares in 1962 was similar to that in 1961 in a boll weevil population dynamics study conducted at Stoneville, Miss. Progeny from populations of 14, 25, 50, and 100 overwintered weevils per acre on cotton grown in replicated field cages damaged 31.0, 55.5, 71.0 and 86.0% of the squares, respectively, during the first generation. These data compare with 25.5, 36.5, 60.5, and 79.5% from a similar test in 1961. Second generation weevils from the four overwintered populations damaged 89.0 to 98.5% of the squares in 1962 and 62.0 to 95% in 1961. In the same study in 1962 yields of seed cotton were inversely related to overwintered boll weevil populations. Plots with estimated populations of 0, 14, 25, 50 and 100 overwintered weevils per acre yielded 2150, 1716, 1333, 1270 and 1091 pounds of seed cotton per acre, respectively. A difference of 411 pounds per acre was required for significance. No statistical differences in quality of lint or staple length were found between treatments.

Fatty acids of the boll weevil and cotton pollen were similar in studies at Florence, S. C. The presence or absence of various fatty acids in the boll weevil at various stages of development and in cotton pollen was determined. Palmitic, stearic, oleic, linoleic and linolenic constitute the major fatty acids in all stages of weevil development, and, also, in cotton pollen.

Studies at Baton Rouge, La. showed that newly emerged adults have about 2% of their lipids in the triglyceride range; non-diapausing two week old adults, 40 to 50%; and diapausing adults as much as 75%. The major factor influencing the type of fatty acids deposited in the triglycerides is the adult diet and it is independent of the diapause non-diapause relationship. Boll-fed adults have a larger amount of oleic than palmitic acid but this is reversed in square-fed weevils.

Nineteen amino acids were identified from the feces of the boll weevil in studies at State College, Miss. There were an additional 9 peaks on the amino acid analyzer which have not been identified. Nitrogen determinations of the feces indicated significant differences between square-fed and diet-fed weevils.

The generalized pattern of triglyceride fluctuation in the boll weevil was determined in studies at Baton Rouge, La. Newly emerged weevils have about 2% of their extractable lipids in the triglyceride fraction, but the level builds up rapidly and reaches 75-85% after 2 to 3 weeks of feeding. The lipid material is drawn upon slowly during the winter, and the storage seems sufficient to allow the insect to survive well into the next cotton season. Free fatty acids and the monoglycerides and diglycerides and free sterols (Fraction III) increase during the overwintering of boll weevils as compared with the decrease in triglycerides. In the fall, field weevils have 14% of their lipids in Fraction III but this increases to 40% by the following June. This shift probably reflects the metabolic utilization of the triglyceride fatty acids leaving the lesser acylated members as the metabolic products.

In studies at Baton Rouge, La., fifteen fatty acids were detected in boll weevil feces. Palmitoleic acid was the major component, palmitic acid second, and the usually large oleic acid component was quite reduced in amount. There was also a 10-fold increase in the short chain fatty acids as compared with body fat. The C-18 polyunsaturated fatty acids (linoleic and linolenic) were not detected in the triglyceride fraction of weevils reared on a fat-free larval diet. Traces of these acids were detected in the phospholipid fraction of the same weevils. Oleic acid was the major fatty acid in both triglycerides and phospholipids and accounted for about 60% of the total.

In studies at Baton Rouge, La., the glyceride fractions obtained from boll weevil and cotton plant lipids proved to be true glycerides because they yield fatty acids and glycerol upon hydrolysis. The R_f values obtained by chromatography with the glycerol hydrolyzed from boll weevil and cotton plant glycerides are identical with the R_f value of authentic glycerol obtained with the same method.

In studies at Florence, S. C., the major phospholipids identified in the boll weevil were phosphatidyl serine, phosphatidyl ethanolamine, phosphatidic acid, sphingomyelin and phosphatidyl choline.

In a study of the metabolism of Bidrin by bollworms, boll weevils and the cotton plant at College Station, Tex., seven degradative products were isolated and five of them identified. One of the remaining metabolites was tentatively identified. One-day-old cotton seedlings, grown from Bidrin-treated seed, had degraded more than 50% of the total Bidrin absorbed during germination.

In studies at the Boll Weevil Research Laboratory the amount of nitrogen excreted as uric acid was dependent upon the diet of the boll weevil. Boll-fed weevils excreted more uric acid than square- or diet-fed weevils. Different boll weevil strains excreted approximately equal amounts of uric acid when fed on squares.

The occurrence of quanine as an excretory product in boll weevil feces was confirmed at the Boll Weevil Research Laboratory. A search of the literature has turned up no instance of quanine being reported as an excretory product in any insect. Feces of the plum curculio were examined and quanine was not found. It is generally found in arachnids.

Free and bound amino acids in Gossypium thurberi bolls were analyzed by ion exchange chromatography at Baton Rouge, La. An unusually large amount of asparagine was found in the free amino acid extract. The total bound amino acids amounted to about one half that found in cotton (G. hirsutum) square anthers. This information should be helpful in the development of more suitable diets for the thurberia weevil.

A technique was developed at the Boll Weevil Research Laboratory in which an infrared gas analyzer was used for measuring respiration rates in intact weevils under conditions where certain environmental factors can be controlled. In experiments using the technique it was found that variations in atmospheric CO_2 concentration in the range of 86-585 p.p.m. have little or no effect on respiration rates in the boll weevil. Under conditions of low relative humidity a temperature response curve was obtained with a thermal death point at 43° C.

In studies at Baton Rouge, La. the incorporated fatty acids of boll weevils and thurberia weevils reflected acids contained in the diet. The route of fat accumulation appeared to be a direct esterification of dietary fatty acids with glycerol. Fatty acids in field-collected thurberia weevils are different from those in boll weevils. However, their fatty acid content can be changed to resemble those of the boll weevil by rearing them on the artificial boll weevil larval diet and by feeding adults on cotton squares.

In studies at Florence, S. C. similar fatty acids were found in selected lipid fractions in boll weevil strains of Mexican and local origin. However, differences were found in the fatty acid pattern between lipid fractions from eggs, newly emerged weevils and 7- to 12-day old adults. The nonphospholipid fraction constitutes a greater percentage of lipid in the egg, newly emerged adult, and 7- to 12-day old adult than the three classes of phospholipids.

Sixteen amino acids and ammonia were present in boll weevil feces in studies at the Boll Weevil Research Laboratory. Ammonia, proline, serine, glutamic acid and leucine all were present in concentrations greater than 6 micromoles per gram of feces.

On studies at the Boll Weevil Research Laboratory the number of chromosomes of the boll weevil was determined to be 44. Nine different cultures from various laboratories were subjected to cytological examination and all contained the same number of chromosomes. Thurberia weevils were also examined but it was not possible to obtain clear metaphase figures because the weevils were in diapause.

A male boll weevil collected on May 28 at Tallulah, La. had five perfectly formed testes. The weevil was in the intermediate stage of diapause. Two testes were on the right side and three on the left side.

A procedure was developed for decontaminating boll weevil eggs at Baton Rouge, La. An 18% solution of cupric sulfate applied to the eggs for 3 to 5 minutes almost completely prevented microbial contamination from appearing in the larval rearing medium. This procedure solved an unusually severe contamination problem.

In studies at Baton Rouge, La. boll weevil oviposition was increased when frozen squares were used for feeding and oviposition. As much as a 3-fold increase in egg production was obtained when the use of frozen squares was compared with fresh squares. Increases were also obtained with frozen bolls over fresh bolls. Because of rapid decomposition of the frozen squares eggs must be removed from them within 24 hours. Microbial contamination is greater when frozen squares are used but this is easily prevented with the cupric sulfate treatment.

An improved machine to mechanically remove the bracts from squares and small bolls was developed at the Boll Weevil Research Laboratory. The machine can debract one pound of squares and bolls per minute. When squares and bolls are debracted the mechanical extraction of boll weevil eggs from them is facilitated in the rearing laboratory.

A machine was devised at the Boll Weevil Research Laboratory for mechanically implanting boll weevil eggs into a larval medium. Previously eggs were implanted manually, one by one. It required about one hour to manually implant eggs in 12 petri dishes containing a larval medium. The device permits a technician to implant eggs in from 360 to 600 petri dishes in the same period of time.

In mass aseptic rearing studies at the Boll Weevil Research Laboratory, 25 to 30% of implanted eggs yielded adults. Following surface sterilization, eggs are aseptically transferred into Erlenmeyer flasks containing larval diet which has been treated with bulk materials that roughen the surface.

In studies at Baton Rouge, La. the addition of more amino acids and soy protein to adult boll weevil diets containing finely ground cotton square powder increased egg production. Weevils laid about as many eggs when fed on the artificial diet as when they were fed on fresh or frozen cotton squares. The ultimate aim of the studies is to devise a diet containing nearly the same amounts of bound and free amino acids as the cotton square. Such a diet should result in high egg production.

In studies at Baton Rouge, La., the minimum concentration of cholesterol in the diet that permitted normal boll weevil larval development was 20%. This concentration is about twice as high as the figure reported previously by other workers using a different larval diet. Results from these experiments will be used to study the synergistic or "sparing" effect of cholesterol by cholestanol and its resultant effect on resistance of the boll weevil to insecticides.

In nutrition studies at Florence, S. C. adult boll weevils fed on a dried egg diet with soybean lecithin and oil added laid more eggs than those fed on the dried egg diet without the added items or than those fed on a germinated cotton seed diet. The diet is now used as the standard adult diet in the rearing program at the laboratory.

In studies at the Boll Weevil Research Laboratory eggs obtained from a boll weevil-thurberia weevil cross were as viable as those from intra-strain crosses. One of nine crosses, thurberia weevil male x boll weevil female laid 9.1 eggs per female per day. Limited observations indicated that thurberia weevil females, regardless of the male parent, laid larger eggs than boll weevil females.

A male boll weevil was reared from an egg laid by a virgin female at the Boll Weevil Research Laboratory. A total of 105 eggs obtained over a three-week period from 50 virgin females was observed for embryonic development. Seven of the eggs hatched and the larvae were placed on artificial media. Six of the larvae died soon after hatching but the seventh developed into a male. He was mated to 3 females of the same strain and the females laid fertile eggs. The parthenogenetic male had a normal chromosome complement.

2. Pink Bollworm. In studies at Brownsville, Tex., the median longevity of laboratory-reared adult female pink bollworms was 40 days, and that of adult males was 54 days, at a constant temperature of 60° F. Females lived a maximum of 93 days and males 106 days. Oviposition was low with a mean of 21.8 eggs produced per female.

Over a 10-year period, 1953-1962, at Waco, Tex., the numbers of moths collected in a light trap were low during April, May, June, and July, but increased considerably in August. The greatest numbers were collected in September each year indicating that general moth movement increases late in the season as cotton matures and immature fruit becomes scarce in many fields. The total number of moths collected in the trap increased each year from 1953 to 1958. There was a sharp decrease in numbers collected in 1959, 1960, 1961, and 1962 from that of 1958, the year in which the greatest number was collected.

In studies in Arizona pink bollworms diapaused in cocoons in the soil instead of remaining in bolls. Larvae which emerged from cotton bolls late in November were placed in emergence cages for observation. Within an hour 60% of the larvae had bored into the soil. After 24 hours, 88% had entered the soil. Data in the previous year were similar.

3. Other Cotton Insects. Twenty percent of bollworm larvae collected on cotton near Waco, Tex., in 1962 were tobacco budworms. Periodic collections of bollworm larvae made in McLennan and Falls Counties were submitted to the Insect Identification and Parasite Introduction Research Branch and to Dr. J. R. Brazzel of the Texas Agricultural Experiment Station for determination of species. Of 1,943 larvae, 388, or 20% were tobacco budworms (Heliothis virescens). Others were the bollworm (Heliothis zea). Percentages of H. virescens collected during the various months were as follows: May, 0; June, 37; July, 10; and August, 32.

Bollworm (Heliothis zea) moths were collected in every month of the year in light traps at Brownsville, Tex. Tobacco budworm (H. virescens) moths were not collected in the months of November, December, January and February. In 1962 the greatest numbers of H. zea were collected in July and of H. virescens in August.

In studies at Brownsville, Tex. the ratio of Heliothis virescens to H. zea was high in the Lower Rio Grande Valley of Texas until June 1, 1963. Eighty-five percent of the bollworm population was the tobacco budworm but only 3 of 78 fields had damaging infestations. During the first two weeks of June, the abundance of the tobacco budworm decreased to 32%, but 13 of 23

fields had damaging infestations of the bollworm complex. Of 91 larvae found on tomatoes 38% were H. virescens. This species was not found on corn, sorghum, alfalfa, lettuce, and cabbage. H. virescens adults were collected in light traps earlier and total numbers of both species collected were higher in 1963 than in 1962.

In studies at Waco, Tex., in 1963 a high percentage of the bollworm populations in Falls and McLennan Counties of Central Texas was Heliothis virescens early in June, by mid-June the population consisted of about equal numbers of H. virescens and H. zea and by the end of the month a high percentage was the latter species. Records for 11 of 13 years (1950-1962) showed that damaging bollworm infestations did not occur in this area until the first or second week of July. In 2 years injurious infestations occurred in a few fields during the last week of June. In 1963 injurious infestations occurred early in June and increased throughout the month with injurious infestations occurring in most fields by the end of June.

Results of studies at College Station, Tex. showed that ascorbic acid is necessary for adult bollworm moths to produce vigorous offspring. Adult bollworm moths fed ascorbic acid produced more vigorous larvae then moths fed only honey and water. Arabo-ascorbic acid will partially replace ascorbic acid in the bollworm larval diet. Chemical analyses for ascorbic acid content of all life stages of the bollworm showed the importance of continuous feeding of this vitamin for production of healthy insects.

Low light intensity and air movement improved bollworm mating in the laboratory at College Station, Tex. Tests indicated that environment is the major factor affecting mating. Moths in 6x6x6 inch cages covered on one side with black cloth and on three sides with aluminum foil were placed in an incubator with 13½ hours of dim light provided by a 10-watt light bulb. Relative humidity of 80 to 90% was maintained and air was circulated through the incubator. Under these conditions mating was consistently above 50% whereas previously with more illumination in the same incubator mating was very poor. A comparison of these results with those obtained with moths kept in a window box during the summer of 1962 when good mating was obtained indicated that optimum mating will be obtained when moths are held under variable light conditions such as exist on a typical June day with high humidity and air currents.

In studies conducted at Brownsville, Tex., to reduce Aspergillus flavus and A. niger contamination in cabbage looper rearing media, formalin and dichlorophene incorporated in diets at 1.4 and 0.25 mg./ml., respectively, significantly affected adversely the growth and development of cabbage loopers. Concentrations tested ranged from 0.4 to 10.4 mg. of formalin/ml. of medium and 0.01 to 1.0 mg. dichlorophene/ml. of medium. Concentrations of dichlorophene which would inhibit growth of contaminants were deleterious to the cabbage loopers.

Ascorbic acid was necessary in cabbage looper diets in studies at Brownsville, Tex. Larvae fed on the basic pink bollworm diet devoid of ascorbic acid developed very slowly and death usually occurred before the third instar. The addition of ascorbic acid and cotton leaf meal to the diet permitted normal development of pupae. When the cotton leaf meal was omitted duration of the larval stage increased and the number and weight of pupae decreased.

Studies at Tucson, Ariz., indicated that white horsenettle is an important host of lygus bugs, especially in non-alfalfa growing areas. Net sweepings of 1-foot high horsenettle Solanum elaegnifolium plants which were growing in scattered lots within cottonfields showed that they were heavily infested with the lygus bug, Lygus hesperus. As many as 129 adults and 28 nymphs per 100 sweeps were collected on these plants in June.

At Stoneville, Miss., twenty one lygus bug adults were recovered from surface woods trash collected between February 25 and March 2, 1963, in Mississippi to determine boll weevil survival. The lygus bugs were fed on cotton squares and bolls initially and later on green snapbeans. Sixteen died by March 12 probably because of mechanical injury inflicted in the recovery process. The 5 which survived lived an average of 41 days.

In preliminary tests at Stoneville, Miss., Lygus nymphs fed on boll weevil larval diets molted and adults fed readily on a modified adult diet indicating that it may be feasible to rear them on an artificial diet.

Differences in plant damage caused by Tetranychus telarius and T. cinnabarinus were observed in the Mississippi Delta. T. telarius infestation caused plant defoliation in limited areas but infestation by T. cinnabarinus did not result in severe leaf drop. Considerably more webbing was present with the latter species. Inexperienced personnel could soon learn to differentiate between the species through observation of the differences in plant damage and degree of webbing. Individual leaf damage caused by the species appeared different, also.

Tetranychus lobosus and T. telarius were collected on cotton for the first time near Waco in McLennan County, Tex., in 1962. Spider mites collected from two fields on July 25 were determined to be T. lobosus and two collections made on August 3 were T. telarius. Specimens from other fields in the vicinity were determined to be T. cinnabarinus and T. desertorum. For many years the latter species was the only one which was collected in the area.

In studies at Tucson, Ariz., the predominant species of black fleahoppers in cottonfields was determined to be Spanagonicus albofasciatus. Of 26,000 black fleahoppers collected over a 3-year period, 93% were this species. Although collections began in April and extended into September, most of the insects were collected in June and July.

In laboratory studies at Tucson, Ariz., the number of instars in Spanogonicus albofasciatus was six and the oviposition period 10 days. Under an average temperature of 78° F. and 55% relative humidity, eggs hatched in nine to eleven days with the greatest number hatching in ten days. There were six instars from egg to adult with a development period of 12 to 14 days.

B. Insecticidal and Cultural Control.

1. Boll Weevil. In field experiments at Tallulah, La., four spray applications of Guthion at 0.25 pound per acre at 7-day intervals with the first applied when the cotton was in the pinhead square stage and the last on July 3, 1962, kept infestations of the boll weevil at a very low level until August 15 when only boll protection was needed. Two applications of DDT, made during the latter part of July, provided adequate bollworm control. Results were similar in 1961 and 1960.

In a randomized and replicated large field plot test at Tallulah, La., methyl parathion-DDT, applied at 7-day intervals with applications beginning at the pinhead-square stage, gave better boll weevil and bollworm control than toxaphene-DDT applied in the same manner, or than methyl parathion-DDT, or toxaphene-DDT applied at 5-day intervals with applications beginning when approximately 15% of the squares were punctured by weevils.

In field experiments at Waco, Tex., Guthion-ethyl Guthion at 0.65 pound and Imidan at 0.65 pound plus DDT at 1.3 pound compared favorably in boll weevil control with Guthion at 0.3 pound plus DDT at 1.3 pound per acre. Monsanto CP-40294 or Bayer 29493 at 0.65 pound plus DDT at 1.3 pound were less effective. Zectran gave boll weevil control equal to that of Sevin when each was applied at 1.5 pounds per acre. At Stoneville, Miss., 0.25 pound

of Guthion-ethyl Guthion, and 0.5 pound dosages of Bayer 25141 or Stauffer R-1504 were as effective against boll weevils as Guthion at 0.25 pound per acre. American Cyanamid 43064, and Bayer 41831 at 1.0 pound, and Monsanto CP-40294 at 0.5 pound, were more effective than methyl parathion at 0.25 pound plus DDT at 0.5 pound per acre.

At Stoneville, Miss., fall applications of methyl parathion spray in 1961 in a large-scale experiment designed to prevent diapause development in boll weevil populations were not sufficiently effective to prevent damage from this insect in the subsequent cotton-producing season. Although weevil populations were reduced, several insecticide applications were required during 1962 to prevent loss in yield.

At Waco, Tex., good increases in seed cotton yield were obtained in treated over untreated plots in 1962. In 8 experiments the average increase in yield from treated over untreated plots was 522 pounds of seed cotton per acre or 83.5%. This compares with an average increase of 393 pounds or 55.7% for the 23-year period 1939-1961. The average number of insecticide applications used during the period was 6.0 and compared with 8.4 in 1962.

Results of small cage field tests at Florence, S. C., indicated that after 48 hours Sevin and mixtures of Geigy 30494, Guthion, malathion, methyl parathion, Methyl Trithion, Monsanto CP 40294, Strobane, or toxaphene with DDT were about equal in effectiveness against the boll weevil. Without added DDT, however, only Guthion and Sevin were highly effective after 48 hours. DDT appeared to increase residual effectiveness of all materials except Guthion. However, the immediate effectiveness (4-8 hours) of the organic phosphorus compounds with DDT appeared to be slightly decreased. In replicated field tests Stauffer R-1504-DDT was equal to Guthion-DDT, and Guthion-ethyl Guthion was superior to Geigy 30494-DDT, and Methyl Trithion-DDT against the boll weevil.

Sugar and agar prolonged the effectiveness of methyl parathion against the boll weevil in field cage tests at the Boll Weevil Research Laboratory. When these materials were added to a standard emulsifiable formulation of methyl parathion, increased kill was obtained at a dosage of 0.125 pound per acre. When the sugar and agar were added to higher dosages of methyl parathion, kill in 3-day residual tests was more than twice that of the same dosages without sugar and agar.

In laboratory tests at the Boll Weevil Research Laboratory, Hercules 7845, Bayer 4790, and Shell SD 5539, each applied at 0.25 pound per acre, gave 100% kill of boll weevils. They were more effective than the methyl parathion standard.

The effectiveness of methyl parathion against the boll weevil increased at high temperatures or when used in combination with DDT in studies at Stoneville, Miss. In laboratory tests with topical applications, 90% of the weevils were killed after 48 hours with a methyl parathion dosage of 0.0218 mg./g. of weevil weight at 80° F. There was no mortality with the same dosage at 50°. Thirty-three percent kill was obtained at 50° when the dosage was increased to 0.644 mg./g. of weevil weight. A methyl parathion dosage of 0.0195 mg./g. of weevil weight combined with a DDT dosage of 1.8116 mg./g. of weevil weight gave 90% kill at 50° F., 48 hours after treatment. The same dosage of DDT alone gave a kill of 50%.

In tests at College Station, Tex., American Cyanamid dithiolane compounds showed promise as systemic insecticides for boll weevil control. Compounds 47031, 47470, and 47071 applied as seed treatments at 1.0 pound per acre were more effective against boll weevils than phorate at the same dosage. When the compounds were applied in granules in the furrow or 3 inches below the furrow at planting time at 0.5 pound per acre, 47031 and 43064 were more effective against boll weevils than 47470, 47071 or phorate.

In tests at Florence, S. C., three adjuvants--Armour arquad C, Arnold Hoffman AH Co. DD-50, and Enjay Laboratories Tridecyl dimethyl benzyl-ammonium chloride significantly enhanced the systemic activity of Zectran in the cotton plant against the boll weevil. Of the 87 commercially available adjuvants used in the induced immunity program, only the above--all quarternary ammonium chlorides--enhanced the insecticidal activity of Zectran. There was no effect on the activity of phorate with any of the materials tested.

In studies at Baton Rouge, La., boll weevils collected in the fall of 1962 near Tallulah, La., continued to be susceptible to methyl parathion. The LD 50s for 2-week old reproducing weevils were only slightly higher than for 2 day-old weevils. Thus far no field population has been found that is as resistant to methyl parathion as the laboratory culture at Louisiana State University which has a four-fold resistance level.

At Waco, Tex., the effectiveness of several insecticides against overwintered boll weevils was evaluated under field conditions by placing one pint ice cream carton cages over the terminal buds of cotton plants in which weevils were found immediately after insecticides were applied to field plots. Stauffer R-1504 at 0.5 pound, Bayer 41831 at 1.0 pound, Guthion at 0.125 pound plus ethyl Guthion at 0.125 pound, and Guthion at 0.25 pound per acre, gave kills of 100%; Bayer 25141 at 0.5 pound 95%; Monsanto CP-40294 at 0.5 pound 90%; and Shell SD-3562 at 0.25 pound per acre 89%.

In a field test at Waco, Tex., American Cyanamid CL 47031, CL 47470 and phorate were applied as granular formulations in the seed furrow at planting time at rates of 2.1, 1.3 and 1.25 pounds per acre, respectively. A phorate seed treatment at 1.0 pound per acre was included in the experiment. Two and 3 weeks after planting, and 7 days after weevils were caged on plants, kills in the AC-CL 47031 treatment were 81 and 41%; in the AC-CL 47470 treatments, 100 and 54%; in the phorate-in-furrow granular treatment, 100 and 54%; and in the phorate seed treatment, 96 and 67%. Four weeks after planting weevil kill was very low in all treatments.

2. Pink Bollworm. In laboratory tests at Brownsville, Tex., Upjohn U-12927 was effective against pink bollworms at 2 pounds per acre and TDE compared favorably with DDT. In a field experiment with replicated treatments, Bayer 37344 at 1.9 pounds and Sevin at 2 pounds per acre gave excellent control of the pink bollworm. Imidan at 1 pound and Bayer 44646 at 2 pounds per acre were less effective.

Simulated spring tillage increased survival of pink bollworm larvae in a treatment in which bolls were buried at a depth of 2 inches. Infested bolls stored during the winter were buried at a depth of 2 inches on April 1, 1962, at Heavener, Okla. Spading the soil covering the bolls in mid-April and again in early May resulted in a pink bollworm survival of 98% while the survival in a similar treatment receiving no cultivation was 65%. Survival was determined by adult moth emergence.

Laboratory results at Brownsville, Tex. showing varying degrees of resistance to DDT in pink bollworm populations from several localities in Texas furnished the first evidence of such resistance in the United States. The greatest resistance (5-fold) was found in moths from Presidio. Pink bollworm resistance to DDT in Mexico was suspected in 1959 and verified in 1960.

In hibernation cage studies at Tempe, Ariz., pink bollworm survival was higher in buried bolls than in bolls on the soil surface in the winter of 1962-1963. Averages of 16.2, 10.1, and 13.1 moths per cage emerged from infested bolls buried 2,4, and 6 inches respectively. An average of 9.5 moths emerged from bolls on the soil surface. Results were similar to those of 1958-1959 when the winter was also quite dry.

3. Other Cotton Insects. In field experiments at Waco, Tex., Guthion at 0.65 pound and Imidan at 0.65 pound plus DDT at 1.3 pound compared favorably in bollworm control with Guthion at 0.3 pound plus DDT at 1.3 pound per acre. Monsanto CP-40294 at 0.65 pound and Bayer 29493 at 0.65 pound plus DDT at 1.3 pound were less effective. Zectran gave bollworm control equal to that of Sevin when each was applied at 1.5 pounds per acre. Both gave better control of bollworms than Bayer 41831 at 1 pound or than Bayer 37344 at 1.5 pounds per acre.

In experiments at Waco, Tex. there was no significant difference between the following acaricides in the control of the desert spider mite 1 and 5 days after treatment: parathion; Bayer 29493; Stauffer R-1504; Guthion-ethyl Guthion; and Bidrin, all at 0.25 pound per acre. These materials were better than tetradifon at 0.5 pound per acre. However, the best residual control after 11 days was obtained with Bidrin, Guthion-ethyl Guthion, and tetradifon. At Stoneville, Miss., one application of Bidrin at 0.1 to 0.2 pound per acre gave control of the two-spotted spider mite for 3 to 4 weeks.

In tests at College Station, Tex., American Cyanamid CL-43064 was as effective against the desert spider mite as phorate, and CL-47031 and CL-43064 were as effective as phorate against the cotton aphid, when the compounds were applied in the furrow or 3 inches below the furrow at planting time at 0.5 pound per acre.

In laboratory tests at Tucson, Ariz., Mobil MC-A-600 at 2 pounds; Stauffer B-10095, B-10498, N-4168, N-3336 and N-2793 at 1 pound; Stauffer B-9381, B-10341 and B-10497 at 0.5 pound; and Bayer 51580, Monsanto CP-19203 and Stauffer R-6032 at 0.125 pound per acre; were effective against lygus bugs. MC-A-600 at 2 pounds and Stauffer B-10341 at 1 pound per acre gave 86% kill of 2nd- and 3rd-instar salt-marsh caterpillar larvae. Shell SD-8211, SD-8436 and SD-8972, and BASFI-155, at 1 pound gave 80 to 85% kill of second- and third-instar bollworm larvae. Stauffer B-10095 at 0.5 pound, and Hercules 7845C and 7846D at 1 pound, gave 87 to 90% kill of third- and fourth-instar cotton leaf perforator larvae. In tests at Brownsville, Tex., Bayer 45556 and 44646, Monsanto CP-40294, Shell 8447, endosulfan, Telodrin and Zectran at 0.5 pound, methyl parathion and Phosdrin at 0.25

pound, and TDE at 1 pound per acre, were effective against the bollworm. Bayer 44646, methyl parathion, Telodrin and Zectran at 1 pound per acre were effective against the tobacco budworm.

Good kills of cabbage loopers were obtained with Zectran at 1.5 pounds and Bayer 44646 at 0.5 pound per acre in a field cage test 48 hours after treatment at Waco, Tex. Endrin at 0.5 pound was less effective. After 10 days, Zectran and Bayer 44646 gave kills of 90% and endrin, 65%.

In a field experiment at Waco, Tex., there was no significant difference in thrips control among American Cyanamid CL 47031, CL 47470, and phorate, applied as granular formulations in the seed furrow at planting time at rates of 2.1, 1.3, and 1.25 pounds per acre, respectively, or phorate as a seed treatment at 1.0 pound per acre.

In a field experiment at Tallulah, La., 10% Di-syston granules applied at rates of 2.5, 5 and 10 pounds per acre in the seed furrow at planting time failed to give satisfactory control of a heavy thrips infestation. The 10-pound rate gave better control than the lower dosages but it was not good enough to prevent damage.

In field experiments at Waco, Tex., Stauffer R-1504 at 0.25 pound, Monsanto CP-40294 at 0.25 pound, Shell SD-3562 at 0.1 pound, and Guthion at 0.125 pound plus ethyl Guthion at 0.125 pound, gave control of thrips equal to that obtained with Guthion at 0.25 pound or toxaphene at 1.0 pound plus DDT at 0.5 pound per acre. Good control of cotton fleahoppers was obtained with Shell SD-3562 at 0.1 and 0.2 pound, Monsanto CP-40294 at 0.25 pound per acre, and toxaphene at 1.5 pound plus DDT at 0.75 pound per acre. Guthion at 0.25 pound, Guthion at 0.125 pound plus ethyl Guthion at 0.125 pound, and Dylox at 0.5 pound, were less effective. Stauffer R-1504 at 0.5 pound per acre gave poor control.

C. Biological Control.

1. Boll Weevil. Studies at the Boll Weevil Research Laboratory showed that the spores of a Schizogregarine, a member of the genus Mattesia, are capable of infecting all larval instars as well as boll weevil adults. Infected late instar larvae may transform to the adult stage but the adult dies shortly thereafter. In tests with adults the disease became evident about one week after spore ingestion. Peak mortality occurred two weeks after ingestion and almost all adults died by the end of the third week. Egg production was reduced drastically in diseased females, averaging less than one egg per day per female

for 4 days prior to death. A second disease, caused by a large rod-shaped motile bacteria, has been increasing in various laboratory cultures.

A method was developed for extracting and purifying Mattesia spores from diseased boll weevils. The final preparation was diluted to one million spores per ml. Studies indicated that diseased females can pass the disease to their progeny. However, per os, infection was the most important means of transmission within the laboratory culture.

Studies also showed that Mattesia spp. spores may be stored for as long as 2 months without loss of infectivity against the boll weevil. The spores may be stored in several ways at 4° C. At that temperature they have been stored in a distilled water suspension for 77 days, and for 2 months in distilled water suspensions or dried on glass and held at 5% or 95% relative humidity without any detectable decrease in infectivity. At 21°-24° C. storage of the spores in cadavers of host weevils resulted in decreased viability after 30 days. Storage of the spores at 50° C. resulted in total loss of infectivity after 10 days. The spores were rendered noninfective by immersion in 2% formaldehyde for 30 minutes or in Lugol's iodine solution for 15 minutes.

In studies at the Boll Weevil Research Laboratory female boll weevils infected with the sporozoan Mattesia laid approximately one third as many eggs as uninfected females. Diseased females laid an average of 1.2 eggs per day but no eggs were laid after the ninteenth day of the tests. Healthy females laid an average of 3.8 eggs per day and almost one half of the females were alive and laying eggs on the day that the last diseased individual died.

A parasite, Microbracon mellitor, parasitized 11.5% of boll weevil larvae in untreated fields in the vicinity of State College, Miss. This parasite oviposits its egg after the weevil larva begins to develop.

2. Pink Bollworm. In studies at Brownsville, Tex., Bacillus thuringiensis influenced development of the pink bollworm. When first instar larvae were exposed to increased doses of B. thuringiensis spores the following corresponding changes occurred: (1) increase in the time required for pupation, (2) decrease in pupal weight, and (3) decrease in number of survivors. There was no difference in adult emergence from pupae recovered from the various dose treatments of spores.

3. Other Cotton Insects. At Brownsville, Tex., the cabbage looper virus was mass produced in the laboratory. The polyhedra were produced from larvae reared on a semi-synthetic diet and it was demonstrated that this procedure can be used to supply polyhedra for general field application. The polyhedra produced from cabbage looper larvae reared on a semisynthetic diet proved effective in field cage trials on cotton in 1962. Two early applications of the polyhedra reduced the larval population approximately 97%. The applications were also of value in maintaining a low level looper infestation during the second generation.

A bioassay technique was developed to determine the pathogenicity of cabbage looper polyhedra suspensions. The technique employs a semisynthetic diet for rearing the larvae and for presenting the polyhedra to be tested. The LD-50 was 237.2 polyhedra/µl. of medium with 95% fiducial limits ranging from 209.9 to 269.3 polyhedra/µl. The LT-50s for 25,000, 1500, 500, and 350 polyhedra/µl. of medium were 3.7, 4.5, 5.0, and 8.0 days, respectively. Approximately 75% of the total larval mortality occurred during the third to fourth instar.

In a field cage test at Waco, Tex., endrin gave 40% kill of cabbage loopers but a polyhedral virus gave no kill 48 hours after application. After 10 days the polyhedral virus gave a kill of 89% and endrin a kill of 65%. The extremely, hot, dry weather with a low relative humidity which occurred during the experiment may have been responsible for the slow kill obtained with the polyhedral virus.

A polyhedra virus isolated from Heliothis zea caused mortality in field populations of this species on cotton, sorghum, and corn. Laboratory and field studies showed that it can produce a polyhedrosis in H. virescens also. The virus is being produced and stored for field control experiments in a pilot scale operation at the rate of 1,000 virus-diseased larvae per day. In field experiments at Brownsville, Tex., in 1963, one application of a polyhedral virus gave good control of the bollworm on grain sorghum. Significant reductions in infestations were obtained on corn in 3 experiments. The virus also showed promise for bollworm control on cotton.

The pathogen Beauvaria bassiana was not effective against the black fleahopper Spanogonicus albofasciatus, in tests conducted at Tucson, Ariz. A commercially formulated dust (Nutrilite Lot #4004) was liberally applied with a Scott Zephyr duster on 12- to 18-inch high cotton plants. Some of the plants had been sprinkled with water prior to dusting. While there was some mortality of fleahoppers on the dry plants, possibly resulting from the drying effect, there was no significant mortality on

any of the treated plants.

In studies at Brownsville, Tex., an average of 20% of bollworm larvae collected early in the season in 1963 from 4 untreated fields were parasitized as compared with 5% in 5 insecticide-treated fields. No parasitized larvae were collected after insecticide applications became frequent and widespread.

Lepidopterous larvae were parasitized only by tachinids in October collections made at Tucson, Ariz. Bollworm, beet armyworm, and salt-marsh caterpillar larvae were parasitized 8, 20, and 72%, respectively.

D. Insect Sterility, Attractants and Other New Approaches to Control.

1. Boll Weevil. In studies at the Boll Weevil Research Laboratory, two morphological deviants in laboratory cultures appeared promising as genetic markers in the boll weevil. In one, the eye is considerably lighter in color than in weevils in nature and has been designated as milky. In the other, designated bashful, the head of the adult is recessed into the prothorax.

A volatile boll weevil attractant was found in the cotton plant at the Boll Weevil Research Laboratory. Two hundred and seventeen milligrams of crude attractant were extracted with chloroform from 20 liters of water obtained from a freeze-drying apparatus used to lyophilize several pounds of cotton seedlings and squares. The material was a greenish-yellow oil with a terpene-like odor. In laboratory tests the crude oil attracted 10 times as many weevils as the solvent used as a check.

To determine the reaction of the boll weevil to a feeding stimulant, weevils were exposed to chicken heart muscle which had been immersed for 5 minutes in an extract of the stimulant obtained from cotton plant parts. An average of 8 weevils was found on the treated animal tissue as compared with 0.1 on the untreated. The treated heart muscle was extensively damaged by feeding of the weevils on it.

Improvements were made at the Boll Weevil Research Laboratory in obtaining the boll weevil attractant from cotton. A vacuum pump was attached to a manifold containing a dry ice bath to provide a cold drum through which air was pulled from over cotton seedlings grown in sand benches in a greenhouse and covered with polyethylene to form an 8-inch enclosure over them. The ice collected was defrosted and the attractant extracted with chloroform. The extract attracted weevils in ratios (attractant trap:check trap) ranging from 41:0 to 120:1. Similar

extraction of the attractant from a greenhouse cotton atmosphere resulted in assay ratios of 38:1 to as high as 183:1. The method produces a purer sample of attractant with less of the repellent material than those previously used.

An even more efficient method of obtaining the boll weevil cotton plant attractant from greenhouse atmospheres was then devised. Results of preliminary tests in which a pump was used to draw air from a greenhouse in which cotton plants were grown through a column of activated charcoal indicated that the attractant could be collected efficiently and at reduced cost over previous methods. An ether extract of the charcoal was bioassayed and the ratios of weevils, extract:check, observed in 2 tests were 34:1 and 61:0.

A boll weevil repellent was found in the cotton plant at the Boll Weevil Research Laboratory. The residue left after removal of the boll weevil attractant from a chloroform extract possessed very strong repellency to the boll weevil. The repellent prevented weevils from feeding on treated seedlings for 16 hours and on treated squares for 24 hours. The repellent action is olfactory since weevils react to it without physical contact with treated surfaces.

At College Station, Tex., male boll weevils sterilized with 10,000 r of gamma irradiation released at weekly intervals in a large field cage did not eradicate the existing population. In the test cage 28% of the egg-punctured fruit produced weevils as compared with 82% in the control cage. A ratio of 100:5:5 of sterile males:normal males:virgin females was released the first week. In the succeeding 3 weeks only 100 sterile males were released each week.

In tests at the Boll Weevil Research Laboratory very few irradiated boll weevils lived more than 20 days after exposure to 2500 or 5000 r. Mortality was low for the first 10 post-exposure days. More eggs were laid by untreated females mated to treated males than by treated or untreated females mated to untreated males. Complete sterility of both sexes was achieved after exposure to 5000 r but all of the treated weevils died by the twentieth day. When only one sex received 5000 r complete sterility was not achieved. When 2500 r was administered to both male and female and the treated weevils mated, sterility was achieved 10 days after treatment.

In laboratory studies at the Boll Weevil Research Laboratory tretamine was the most effective chemosterilant of 19 compounds tested. Apholate, methiotepa and aphozide were slightly less effective. Mortality greater than 60% occurred within 14 days

after boll weevils were dipped in 1 or 2% water solution of the 4 compounds. The remaining 15 compounds were relatively ineffective.

Eradication of boll weevil with a sterile male technique was demonstrated in an isolated cotton plot in studies conducted by the Boll Weevil Research Laboratory. Ten gravid females were released in a corner of a 6-acre cottonfield in Plaquemines Parish, La., on July 26, 1962. Beginning August 1, apholate-sterilized males were released at a rate calculated to give a preponderance of sterile to normal F_1 males at the peak of the F_1 emergence period. The final release of 100 sterile males of a total of 8,850 was made September 19. No egg-punctured squares were found in the field after November 15. A freeze killed the cotton in December. Twenty apholate-sterilized males released weekly for 8 weeks for each normal male and female originally released in two field experiments in Tennessee and Virginia failed to eradicate or to depress the population build-up.

2. Pink Bollworm. Male moths of the pink bollworm were sterilized with metapa at Brownsville, Tex. When the males were topically treated with 15 ug of metapa per moth and mated with untreated females, only 4 of 13,622 of the eggs laid by the females hatched. No eggs hatched when males treated with 25 µg per moth were mated with untreated females. When males were exposed to a residue of metapa on glass (25.6 µg/cm2) for $\frac{1}{4}$- and 1-hour exposures and mated to untreated females, 5 of 7,416 and 2 of 7,411 eggs hatched. Pink bollworm males treated with metapa (15 µg/moth) caged with 10 untreated pairs per cage in the ratios of 1:1, 4:1, and 9:1 sterile to normal males reduced egg hatch by 50.7, 83.6 and 93.1%, respectively, indicating that the sterile males were competitive with untreated males.

In tests at Brownsville, Tex., release of male pink bollworm adults from gamma irradiated (35kr) pupae in field cages placed over cotton plants infested with untreated pairs at a ratio of 19 treated males to 1 untreated male resulted in a 52% reduction in exit holes in bolls of the F_1 generation when compared with those in cages in which only untreated pairs were released. This reduction was considerably below the theoretical 95% reduction for the release rate used.

3. Other Cotton Insects. A male sex attractant of the cabbage looper was discovered at Brownsville, Tex. The attractant was extracted with methylene chloride from the terminal 2 or 3 segments or "tips" of abdomens of females. Virgin males exposed to filter paper strips impregnated with 1/16 to 1/20 female equivalent of extract from the abdomens exhibited a mating response lasting from 2 to 5 minutes Gases from a component

(or components) emanating from the gas chromatography column attracted the males and then evoked the same response.

E. Evaluation of Equipment for Insect Control and Detection.

1. Boll Weevil. In studies at the Boll Weevil Research Laboratory a tractor mounted 3-flail unit destroyed or removed 76 to 94% of punctured squares spread by hand on row profiles. Higher flail speeds (1800 r.p.m.) were more efficient than lower speeds (1600 r.p.m.). Tractor speeds up to 3.4 m.p.h. were more efficient than a speed of 5.4 m.p.h.

2. Pink Bollworm. In a study conducted at Brownsville, Tex. a fan blowing a stream of air into a light trap at both 100 and 200 feet per minute significantly increased the collections of pink bollworm, other microlepidoptera, and macrolepidoptera over those in a trap without a fan.

In studies at Brownsville, Tex., X-ray was used for detecting pink bollworm in cottonseed. Detection of diapause pink bollworm larvae in cottonseed by a "soft" or long-wave X-ray unit compared favorably with hand-dissection of seed when 100 grams of seed cotton were used per 8 x 10-inch film. The radiographic technique required only one fourth the time required for hand dissection.

In studies at Brownsville, Tex., calcium cyanide was found to be compatible with the pink bollworm sex lure in traps. Modified gypsy moth traps using calcium cyanide as a killing agent collected at least as many pink bollworm moths as traps using tanglefoot as the capturing mechanism.

F. Varietal Evaluation for Insect Resistance.

1. Boll Weevil. Glandless cotton strain 38-6 was more susceptible than other strains exposed to thurberia weevils in a cage test at Tucson, Ariz. Glandless 38-6, which has been more susceptible than other strains to Lepidoptera and lygus bugs, had the highest boll infestation, 24%, of four varieties tested, including glandless 4-42-77 which had only 11% of the bolls infested.

Studies at the Boll Weevil Research Laboratory showed that different cotton strains and species vary greatly in concentration of feeding stimulant. Experimental strain $gl_2gl_2gl_3gl_3$ was very low in feeding stimulant concentration. It is not known whether this is associated with the glandless character or associated characters. In preliminary tests, allohexaploids between Gossypium hirsutum and G. herbaceum and between G.

hirsutum and G. arboreum contained low feeding stimulant properties similar to the Asiatic species in the cross. This indicated probable genetic control of the character. G. thurberi and G. lobatum were low in feeding stimulant.

Studies at the Boll Weevil Research Laboratory indicated that gas chromatography may be used in screening cotton varieties for the presence of the boll weevil attractant. Bioassay has demonstrated that the plant attractant is associated with one or two peaks on the gas chromatograph. Both peaks come off before chloroform indicating that the attractant is highly volatile and readily lost at room temperature. Since the attractant from seedlings also possesses one of the peaks, it may be possible to screen for attractant concentration with the gas chromatograph. The need for bioassay may be eliminated.

In studies at Stoneville, Miss., experimental cotton strains varied in infestations of the boll weevil. Replicated one-row plots of seven experimental strains of cotton showed significant differences in percentages of boll weevil punctured squares. Asiatic strains had the fewest punctures, red plants were intermediate in the numbers of punctures, and the Yugoslav Early strain had the highest percentage of punctured squares.

In laboratory tests at the Boll Weevil Research Laboratory, Gossypium thurberi possessed resistant factors against the boll weevil. These factors were expressed in larval diet studies and resulted in weevils of considerably smaller size than those reared on diets from other cotton species. The effect of square size on weevil weight was eliminated in these tests.

2. Other Cotton Insects. In studies at Brownsville, Tex., significantly fewer bollworm eggs were laid on 5A-3, a glabrous experimental strain, than on the DPL variety in both cage and field plot experiments. In four field cage tests comparing the two cottons, only 8, 27, 18 and 6% of the eggs were deposited on the experimental strain. In plantings in replicated small field plots, 28% of the eggs deposited were on the experimental strain.

Experimental cotton strains showed resistance to beet armyworm, black fleahoppers and lygus bugs in greenhouse flat-screening tests at Tucson, Ariz. In a test for resistance to second- and third-instar beet armyworm larvae, 37 and 40% of the plants of experimental strains 103 and 104 were damaged. Percentages of plants damaged in 19 other strains ranged from 62 to 100. In a test for resistance to blackfleahoppers, less that 10% of plants of six of 20 experimental strains, T-72, T-73, T-74, T-76, T-77 and T-78, were damaged compared with 41% for Calif. 4-42. In a test for resistance to lygus bugs, less than 5% of plants of

12 of 43 experimental strains, T-67, T-73, T-74, T-93, T-95, T-96, T-97, T-102, T-105, T-107, T-110, and T-111, were damaged compared with 42% for Acala 44 and 17% for Calif. 4-42.

In studies at Brownsville, Tex., bollworm development was influenced by gossypol glands on plants. When first-instar bollworms were placed on cotton terminals, the smallest number survived on heavily gossypol-glanded pima cottons. Differences in larval mortality between cotton types were noted after 5 days. The trend was the same when second-instar larvae were confined on squares from the various types. Fresh squares were supplied every second day. Pupae from larvae developing on heavily glanded plants were much smaller than those from plants with fewer gossypol glands.

In studies at Tucson, Ariz., the gossypol content of Gossypium thurberi leaves was greater than the lethal dosage required for the bollworm. The gossypol content of G. thurberi green leaves was 1.283%. One percent of gossypol incorporated into artificial food caused 100% mortality of second- and third-instar bollworm larvae.

In cage tests at Brownsville, Tex., the number of bollworm eggs laid on a nectariless, smooth strain of cotton was one-fifth of that laid on a commercial variety possessing nectaries and epidermal hairs. Larval mortality was higher, and weights of surviving pupae from larvae developing on cotton strains with a high gossypol content were lower than those from larvae developing on a variety with low gossypol content.

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AREA NO. 10. TOBACCO INSECTS

Problem. Profitable production of tobacco depends on the control of insects, particularly budworms, hornworms, flea beetles and aphids. Insecticides that have proved effective for the control of these insects have resulted in undesirable residues on cured tobacco. Such residues adhere to the leaf through commercial processing into cigarettes and some have been found in the main-stream of smoke from commercial cigarettes. There is, therefore, need for the development of effective methods of controlling insect pests of tobacco that will not lead to insecticide residues in cigarettes or other manufactured tobacco products. This would include more intensive research on lures, traps, sterilization, and other new approaches to control; better utilization of predators, parasites, and diseases of tobacco insects; evaluation of tobacco varieties which resist insect attack; and continued research for chemicals that leave no residue.

USDA PROGRAM

The Department has a continuing program involving basic and applied research on tobacco insects to develop effective control methods that will not lead to insecticide residues in cigarettes or other manufactured tobacco products. The program is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway, and with the tobacco industry. Studies are conducted at Oxford, N. C.; Florence, S. C.; and Quincy, Fla.

The Federal scientific effort devoted to research in this area totals 5.7 professional man-years. Of this number, 1.1 is devoted to basic biology, physiology and nutrition; 0.6 to insecticidal and cultural control; 0.1 to insecticide residue determinations; 0.8 to biological control; 2.3 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of equipment for insect detection and control; and 0.7 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Hornworms and Budworms. Studies of the effect of the sucker control chemical MH 30 on overwintering populations of hornworms and budworms have shown that hornworm numbers on suckers after harvest are very greatly reduced in treated fields. Budworms may be reduced if the late suckers are small. On the other hand, the population of diapausing budworms may be increased in some cases if flowering is delayed beyond September 15.

Methods of mass rearing hornworms on field grown tobacco have been improved. A fully grown hornworm larva weighs about 10 grams. It has been estimated that a thousand larvae fed on an artificial diet would require about $400 worth of food. In contrast enough tobacco to feed the same number would cost only about $2.00. Therefore, any practical method of mass rearing hornworms must utilize the natural food. After some preliminary experiments in 1962, about 20,000 hornworms were reared by the following method: Moths were released in a large cage covering a quarter acre of field-grown tobacco. Eggs were laid on the plants and the larvae allowed to reach the fifth and last instar, at which time they were collected by hand and placed on specially designed tables. The top of each table was made of hardware cloth and tobacco was hung on racks above it in such a way that hornworms could feed on the leaves and their feces fall through the wire below. On completion of feeding the larvae dropped to the wire and wandered off the table into a box of sawdust in which they pupated.

In 1963 methods of mass rearing were modified as follows: the moths laid their eggs on a small number of potted plants. Plants were then removed to a heated and lighted room where the larvae hatched and fed on the same plants through the second instar. They were then given additional potted plants as needed until they reached the late fourth or early fifth instar when they were placed on tables similar to those used in 1962 and fed cut tobacco. When ready to pupate each larva was placed in a hole in a wooden block. The 1963 method was all indoors and hence could be more closely controlled with about 75% less labor. A bacterial disease on the rearing tables and in the greenhouse was controlled by spraying the plants with a commercial preparation of streptomycin and terramycin at 200 p.p.m. in water.

Radioactive phosphorus has been used to mark male hornworms in such a way that females mating with them can be identified. Male adults were fed 0.07 microcuries of P^{32} in sugar solution. These males were mated with untreated females. The spermatophores were dissected from the females and placed on X-ray film. The films were developed after two weeks. Spermatophores produced within 12 hours after treating the males did not contain enough radioactive material to expose the film, but those produced at least 24 hours after treatment made a satisfactory picture.

A method of rearing the tobacco budworm on bean seedlings was developed in 1960-61, but laboratory-reared stock failed to lay eggs and died out after five or six generations. Other investigators have had the same difficulty with other Phalinidae. In 1962 the method of handling adults was modified so that instead of collecting eggs from single pairs placed in small cages, many moths were allowed to cross freely in a large cage and lay eggs on young tobacco plants. Seventeen generations have been reared by this method with no indication that the stock is running out.

The chief obstacle to mass rearing budworms on bean seedlings is that the larvae pupate in the tangled mass of roots and soil and are very difficult

to extricate. Some improvement has been made by growing the beans over hardware cloth in such a way that the larvae are forced to pupate above the root mass or in vermiculite placed on the sides.

B. Insecticidal and Cultural Control

1. Wireworms. The importance of wireworms as tobacco pests is illustrated by the fact that more than 70% of the tobacco growers in South Carolina used insecticides for wireworm control in the spring of 1963. The two species of wireworms that are serious pests of newly set tobacco plants have become resistant to most of the chlorinated hydrocarbon insecticides. Therefore, extensive field experiments have been conducted at Florence, S. C., to find more effective insecticides. These experiments have shown that both species can be controlled by either: (1) a preplant broadcast application of 2 pounds per acre of parathion, diazinon, Bayer 25141, or phorate; or (2) by adding from 2 to 3 ounces of a 50% diazinon wettable powder to each 50 gallons of transplant water used with a mechanical transplanter.

2. Hornworms, budworms, and cabbage loopers. On shade-grown tobacco in Florida, Bacillus thuringiensis and endosulfan caused a significant reduction in numbers of hornworms. Endosulfan also reduced the numbers of budworms and cabbage loopers.

C. Insecticide Residue Determinations

1. Endrin. In 1962 endrin residues of 3.15 p.p.m. were found on flue-cured tobacco and 7.8 p.p.m. on cigar wrapper tobacco. Samples of the flue-cured were taken from 50 different piles of tobacco in each warehouse sampled. Three warehouses were sampled in Florida and Georgia, 5 in South Carolina, and 15 in North Carolina. These were analyzed for endrin by the Pesticide Chemicals Research Branch. Endrin was found on the samples from all markets except one. The most endrin on flue-cured tobacco was found in Florida and the eastern belt of North Carolina.

2. Phorate. Phorate applied to the soil for wireworm control had a marked deleterious effect on the quality of the tobacco. In 1962 tobacco was harvested from plots treated with Zinophos, phorate, Kepone bait, and no treatment, and submitted to the American Tobacco Company for tests and flavor evaluation. Zinophos and Kepone had no effect, but phorate applied as 10% granules at the rate of 2 lb. of phorate per acre caused an objectionable taste in cigarettes. Chemical analysis showed that the phorate-treated samples were higher than any of the other treatments in percent total volatile bases and total sugar and lower in nicotine and ash.

D. Insect Sterility, Attractants and Other New Approaches to Control

1. Tobacco Hornworm. At Florence, S. C., field testing of extracts of virgin female hornworm moths proved that they were highly volatile and attractive to males for only one night. Work is underway to stabilize the

sex attractant for use under field conditions and to produce large numbers of female moths for extraction of sex attractant.

A number of years ago several investigators used trap cages that were baited with isoamyl salicylate to capture hornworm moths in the field. While such trap catches did not control the hornworms, a large number of moths could be trapped in this manner. Recently, this type of trap has been baited with a sex attractant to lure male moths. However, most of the moths that got into the trap escaped during the night.

In attempts to sterilize hornworms it has been found that high dosages of gamma radiation are required to kill or cripple the pupae. About 3,000 male pupae taken from overwintering stock but not in diapause at the time of treatment were subjected to doses of gamma radiation varying from 0.5 to 90 kr. Doses up to 50 kr had little or no harmful effect. At 90 kr most of the pupae were killed and less than one percent were normal.

2. Tobacco Budworm. Enough budworms have been reared for preliminary sex attractant experiments. Virgin females were placed in a small tight box with a gypsy moth trap covering an opening at either end. This device when placed in a greenhouse with released males caught males after the females were more than 3 days old. Males of all ages were caught. In another experiment, virgin females were ground with ether in a tissue grinder. The resulting suspension was then filtered and the filtrate evaporated on paper which was placed inside a gypsy moth trap. When exposed in a large cage such traps caught more males than the checks but were not highly attractive.

E. Evaluation of Equipment for Insect Detection and Control

A large area experiment to test the effect of light traps on hornworm populations was set up early in 1962 in cooperation with the Agricultural Engineering Research Division. The test area consisted of two tangent circles each 12 miles in diameter and containing 113 square miles. The eastern circle was equipped with 324 traps or about 3 per square mile. Additional traps were placed at intervals of about a mile for a distance of 6 miles on extended radii from the circumference in four directions. In the western circle four lines of 6 traps each were placed in four directions from the center.

The traps were placed on poles 10 feet high, equipped with a 15-watt black light lamp and arranged so that the hornworms were caught in a cage and could be recovered alive. All traps were placed in open areas near farm buildings in order to obtain electric power, but some were near trees or woods.

During the period July 14 to October 10, 1962, 52 traps were examined daily. When the catch per trap was plotted against the distance outward from the center of the light trap area, there was a significant relation between catch and distance. There was no sharp increase at 6 miles where the

number of traps dropped from 3 to less than one per square mile, but instead there was only a gradual increase in catches out to at least 12 miles or 6 miles beyond the edge of the heavily trapped area. This was true of both species and both sexes. It means that hornworms were moving at least 6 miles through the area and perhaps more. Nevertheless, catches outside the trapped area were definitely higher than inside. The estimated reduction in population between the center of the trapped area and traps 12 miles out was 76% for tobacco hornworm males, 55% for females; and 89% for tomato hornworm males, and 59% for females.

Counts were also made of eggs and first-instar larvae in tobacco fields during this same period. These data show a reduction of about 58% in populations between fields 0 to 3 miles and those 9-12 miles from the center.

Since the number of traps per square mile varied considerably due to the availability of power sources and roads, the trap data show that the total number of hornworms caught increased rapidly up to 3 traps per square mile, but more than 3 traps failed to increase either male or female catches. Some of the females caught were dissected to determine if they had mated. In spite of the fact that the traps caught many more males than females there was little difference in the percent of females mated inside and outside the trapped area. Although females may mate as many as three times, 96% of those captured had mated only once.

This experiment will be continued through 1963.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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AREA NO. 11. SUGARCANE AND SUGARBEET INSECTS

Problem. Insects and mites are major limiting factors in the production of sugar crops because of the direct damage they cause and the diseases they spread. The use of available insecticides to control insects on sugarcane and sugarbeets often leaves residues in the crop byproducts that makes them unsuitable for livestock feed. Heavy rains following applications of insecticides to sugarcane have resulted in some kill of fish in nearby streams. Safe, effective chemical methods are especially needed to control the sugarcane borer and the beet webworm. Sugarcane mosaic has become more important in recent years and information on insect vectors of this disease is needed. The beet yellows and the associated western yellows virus diseases of sugarbeets have become a threat to the sugarbeet industry and are particularly destructive in the Pacific Northwest. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. The development of suitable control measures is handicapped by lack of adequate knowledge of the identity and ecology of the insect vectors and plant reservoirs of the two viruses. For long-range solutions to the problems, further investigations should be undertaken on parasites and predators of sugar-crop pests, on varieties of sugarcane and sugarbeets resistant to the insects involved, and on new insect control approaches such as the male-sterility technique or the development of attractants. Research should aim to develop control methods without objectionable features. Key insect pests that require heavy use of insecticides for their control and thereby make difficult the natural control of other pests on the same crops are special problems that should receive emphasis in the search for non-chemical methods of control.

USDA PROGRAM

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugarbeet directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway, and with industry. Studies on sugarcane insects are conducted at Houma, La., Canal Point, Fla., and Mayaguez, Puerto Rico, and on sugarbeet insects at Mesa, Ariz., Twin Falls, Idaho, Logan, Utah, and Yakima, Wash.

The Federal scientific effort devoted to research in this area totals 8.7 professional man-years. Of this number, 1.0 man-year is devoted to basic biology, physiology and nutrition; 1.9 to insecticidal control; 0.8 to insecticide residue determinations; 1.1 to biological control; 1.0 to insect sterility, attractants and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.5 to varietal evaluation for insect resistance; 1.7 to insect vectors of diseases; and 0.6 to program leadership.

A P. L. 480 research grant (Project A7-ENT-1) has been made to the Commonwealth Institute of Biological Control, Bangalore, India, to study the natural enemies of sugarcane borers in India. Parasites and predators found effective for borer control will be made available for use in the United States.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Sugarcane Insects. In Louisiana the annual 1962 harvesttime survey to determine sugarcane borer infestation showed that 6% of the joints of sugarcane had borer damage with an estimated crop loss of 5%. The low infestation in 1962 resulted from 98% mortality in overwintering borers the previous winter. The infestation average for a 28-year period from 1935 to 1962, inclusive, is 16%. Twenty percent of 50 ratoon fields that were surveyed in June of this year had more than 500 borer-killed dead hearts per acre.

The 1962 harvesttime survey in Florida showed an average of 7.9% joints damaged by the borer for the Everglades area compared to an average of less than 2% for this area during the period of 1955-60. The sugarcane area near Fellsmere, Fla., had an average of 22.6% bored joints as compared to 21.4 in 1961, 19.1 in 1960, and an average of 8.9 during the period 1955-60.

2. Sugarbeet Insects. Biological and ecological studies of the beet webworm in southern Idaho have shown that it is probably the third brood of this insect that causes most damage in sugarbeets rather than the second. The studies have also shown that sugarbeets are not a preferred host, and consequently, the first two broods each season may build up on other hosts. Under laboratory conditions a much higher survival of webworm larvae is obtained from such weeds as redscale, Russian-thistle, and lambsquarters, than from sugarbeet plants.

3. Green Peach Aphid. Agamic forms of the aphid survived the winter of 1962-63 in the crowns of several perennial or fall-germinated weeds in the Yakima Valley of Washington. Aphids were particularly abundant on plants in the protected bottom of deep irrigation drain ditches in an area of intensive sugarbeet culture or along worn north banks of such ditches. Overwintering of this important aphid vector of the destructive beet western yellows disease on the weeds was shown to have particular significance--demonstrating that aphids collected from hoary cress, Lepidium draba, and several other common weeds found in the ditches were carrying the virus. Transfer of these aphids to healthy shepherd's purse (Capsella bursa-pastoris), an indicator plant, resulted in the development of typical beet western yellows symptoms.

At Mesa, Ariz., a handbook on insects affecting sugarbeets grown for seed was prepared for publication. This is based on more than 20 years of research and observation and more than 20 insects are described and

illustrated. The descriptions given permit easy recognition of the major pests of sugarbeets by seed growers and others. Information on beneficial parasites and predators of these pests, other control measures, and on the biology and habits of the insects is also included.

B. Insecticidal and Cultural Control

1. Sugarcane Insects. In experiments in Louisiana, granular insecticides, endrin, Guthion, Methyl-ethyl Guthion, Bayer 25141, U.C. 8305, and carbaryl, gave significant reductions in numbers of sugarcane borers. The most effective material was endrin with 90% control.

In Louisiana, small soil arthropods associated with root rot diseases of sugarcane were controlled with endrin at 1/2 lb. per acre, which increased yield 4.3 tons of cane per acre. Endosulfan at 4 lb. per acre increased the yield 3.4 tons; carbaryl at 4 lb., 1.3 tons; and chlordane (standard) at 2 lb. per acre, 1/3 ton.

In Florida, control of wireworms was attempted with insecticides applied to soils as emulsions. Their effectiveness was measured by increased yield in tons per acre, as follows: Phorate (4 lb. p/a.) 12.7 tons; diazinon (4 lb.) 12.1 tons; diazinon (8 lb.) 11.4 tons; heptachlor (4 lb.) 9.7 tons; aldrin (4 lb.) 8.4 tons; and chlordane (6 lb.) 4.6 tons per acre. Granular formulations increased yield as follows: Telodrin (1 lb.) 11.5 tons per acre; diazinon (6 lb.) 11.0 tons; heptachlor (4 lb.) 8.7 tons; aldrin (4 lb.) 5.5 tons; and chlordane (6 lb.) 3.6 tons per acre.

2. Sugarbeet Insects. Granular heptachlor applied as a soil treatment showed promise for controlling sugarbeet root maggot. Of 50 treatments tested in Idaho for control of this pest on sugarbeets, best results were obtained with 1/2, 1, and 2 pounds of heptachlor per acre. The heptachlor granules were mixed with the seed in drill rows at planting time. The maggot counts in 1/16 cubic-foot soil samples averaged 4, 3, and 2 for these treatments, respectively. There was little or no feeding on the roots except in the check plots where there was moderate to severe damage. Phorate applied in the same manner as heptachlor gave almost as good control but was phytotoxic. Less effective treatments included aldrin, V-C 13, Di-syston, ethion, and carbophenothion applied in the drill row at planting time; aldrin, dieldrin, phorate, V-C 13, and Di-syston applied in pelletized seed; and V-C 13, Menazon, and American Cyanamid 43073 in slurries applied to the seed.

Continued studies in Washington indicate the green peach aphid may be controlled on sugarbeet by applications of phorate or Di-syston to the young beet plants. The insecticide retarded the spread of beet western yellows disease and increased the yields of row beets and sugar. Additional studies are needed to determine how best to apply the insecticides and to develop a treatment program. Tolerances have been established for Di-syston but not for phorate.

Experiments in Utah continued to indicate certain sugarbeet insects may be controlled with insecticides either applied to pelleted seed or incorporated in the material used to pellet the seed. V-C 13 was most promising for control of the sugarbeet root maggot followed by phorate. The latter tended to be more effective than V-C 13 against the garden symphylan. Both materials gave promising results against the beet leafhopper. Both of these materials are considered to be systemic in plants and there is no established tolerance for them in or on sugarbeets. Di-syston which is also systemic and has tolerances established for dried pulp, roots, and tops has also given promising results against root maggots.

C. Insecticide Residue Determinations

Sugarbeets were treated at Twin Falls, Idaho, at planting time with 1/2, 1, or 2 lb. of heptachlor per acre by mixing the insecticide with the seed. Samples taken 113 days after planting and analyzed at Yakima, Wash., contained 0.17, 0.31, and 0.21 p.p.m. of combined heptachlor and heptachlor epoxide in the roots, respectively. One hundred and seventy-eight days after planting, the roots contained 0.09, 0.16, and 0.22 p.p.m. of the two chemicals. Measurable residues of heptachlor and heptachlor epoxide were found in sugarbeet crowns and foliage samples taken 178 days after planting in the case of the 1 and 2 lb. treatments but none in the case of the 1/2 lb. treatment. In view of these results, the use of heptachlor on sugarbeets cannot be recommended.

D. Biological Control

1. Sugarcane Insects. The population density of the West Indian sugarcane fulgorid in Florida has remained low since the spring of 1961. Two species of parasites, Stenocranophilus quadratus and Anagrus armatus, both introduced into Florida in 1959, are credited with the reduction of this pest to a low, non-economic population level.

Sugarcane borer parasitization by Agathis stigmaterus, introduced from Peru in 1932, in commercial fields of the Everglades and Fellsmere, Fla., areas at harvesttime 1962 was about double that reported in previous years, averaging 34 and 21%, respectively.

In Florida, preliminary biological studies of Goniozus indicus and Sturmiopsis inferens, two parasites introduced from India, in connection with P. L. 480 project A7-ENT-1, showed little promise of being able to establish themselves under field conditions in Florida. Results of tests with a third parasite, Apanteles flavipes, also from India, are more encouraging. Approximately 10,000 adults of this parasite have been reared and released in 4 locations in Florida.

Cuban flies survived two successive severe winters in Louisiana. Although low temperatures drastically reduced the overwintering borer population, minimum numbers of this introduced parasite survived. Several unemerged puparia were recovered during May and June from small borer collections of undetermined numbers. Parasitization in Puerto Rico averages 30% in the field.

Collections of borer eggs in fields of sugarcane on eight plantations in southeastern Louisiana during the fall of 1962 showed an average parasitism by Trichogramma of 32%, as compared to 39% in 1961. The usual average is 75%. In Puerto Rico, parasitization averages 75-90%.

Climbing cutworms appear to be suppressed by native parasites in sugarcane areas of Florida. Successive generations of climbing cutworms were not observed in cane of the Lake Okeechobee area this past season. Apanteles rufocafalis, Euplectrus plathypenae, Encelatoria rubentis and two ichneumonid species parasitized the cutworms heavily.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarcane Insects. Studies at Mayaguez, P. R., for developing an artificial medium suitable for mass rearing of the sugarcane borer (Diatraea saccharalis) produced an inexpensive, easy-to-make, corn powder base material that appears to satisfy nutritional requirements. It is composed of distilled water, agar, sucrose, ascorbic acid, corn plant powder, and antibiotics.

Preliminary information suggests that sorbic acid may be instrumental in lengthening the larval life span of the sugarcane borer. Sugarcane borer sex ratios in Puerto Rico are about 1:1 on a year around basis. A high percentage (34-45) of field-collected old adult females lacked spermatophores.

F. Varietal Evaluation for Insect Resistance

1. Sugarcane Insects. Of 237 sugarcane varieties tested in hand-infested plots in Louisiana, in 1962, 50% had a lower infestation, and 55% produced more sugar per acre than standard variety C.P. 36-105. Of 319 varieties assigned C.P. and L. numbers in Louisiana in 1962, 20 were resistant to the borer, 19 susceptible, and the rest moderately susceptible to average. Two varieties, C.P.58-51 and L.56-25, now in advanced stages of development, were especially tolerant to borer infestation and have a good chance of becoming commercial varieties. Only one Florida variety, C.P.59-83, had a lower infestation than control variety, C.P.50-28.

G. Insect Vectors of Diseases

1. Sugarcane Insects. Spring populations of sugarcane mosaic vectors, the corn leaf aphid (Rhopalosiphum maidis) and the sowthistle aphids, Amphorophora sonchi and Macrosiphum ambrosiae, were higher in 1962 than in 1961. These species appear to be the most generally distributed of all known vectors.

At Houma, La., 16 weekly applications of demeton at 1/2 lb. per acre from October 25, 1961 to July 2, 1962, reduced sugarcane mosaic by 41%. Eighty-eight percent of the plants were free of the corn leaf and brick-red sowthistle aphids, 82% of the plants were free of the green pea aphid, and 68% of them were free of the sharp-nosed grain leafhopper.

2. Sugarbeet Insects. At Mesa, Ariz., field plot experiments showed that green peach aphids infected with the virus of either the beet western yellows or the beet yellows reduced the yield of sugarbeet seed. With beet western yellows yields were reduced 13%, and with beet yellows 17%; whereas, with a combination of the two viruses yields were reduced 26%. Symptoms are similar, although the viruses are unrelated. Beet yellows virus is semipersistent, most aphids losing the ability to transmit it in 24 hours. Beet western yellows is persistent in the aphid. Previous experiments had been with mixtures of these two yellows viruses, but the damage to the beet seed crop of either one alone was not understood. Several species of aphids transmit either or both of these viruses but the studies indicate the green peach aphid is the principal vector in Arizona.

The development of the green peach aphid on sugarbeet in relation to various overwintering sources of aphids and the subsequent occurrence of beet western yellows is being investigated in Washington. These studies have shown that aphids are more abundant in fields close to peach orchards where the aphids overwinter in the egg stage than in more remote fields even though the latter may be close to protected places where the aphids are able to feed during the winter. However, the incidence of beet western yellows tended to be higher in fields near these protected places indicating that the small number of active aphids from infected wild host plants is a more important source of virus infection than large numbers of aphids from peach orchards.

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Varietal Evaluation for Insect Resistance

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AREA NO. 12. ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Problem. Ornamental shrubs, flowers, and turf are subject to damage caused by a great variety of insects and mites. More effective and safer control measures are needed for many of these pests. More basic information on the ecology and biology including host plant preferences and distribution of aphids, beetles, mites, thrips and other pests that attack or transmit diseases to these plants is required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable residues in soils are needed. The nature and cause of resistant strains of insects and mites and means to overcome or prevent their resistance to insecticides require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to syncronize or integrate biological control with insecticidal and cultural control methods. Ornamental plants resistant to insect attack should be developed. Controlled light or application of other physical factors as possible means of controlling greenhouse pests should be studied. Increased emphasis should be placed on the search for insect attractants, chemosterilants, and growth- or reproduction-affecting substances.

USDA PROGRAM

The Department has a long-range program of research on ornamental, flower, and turf insects. It involves entomologists, chemists, physiologists and insect pathologists engaged in both basic studies and applied research on growers' problems and on problems of concern to plant pest control and quarantine officials. Basic biology and nutrition studies at Beltsville, Md., and Farmingdale, N. Y., and research on insecticidal and cultural control at Beltsville, Md., Farmingdale and Geneva, N. Y., Moorestown, N. J., and Sumner, Wash., are cooperative with the respective State Experiment Stations. Much of the work at Beltsville is cooperative with the Crops Research Division. Biological control studies at Beltsville, Md., Moorestown, N. J., and Geneva, N. Y., are cooperative with the State Experiment Stations as are studies concerned with insect sterility, attractants, and other new approaches to control. Cooperation is maintained at Moorestown, N. J., and Geneva, N. Y., with the Northern Utilization Research Division at Peoria, Ill., on research to develop methods of mass production of milky disease. Evaluation of equipment for insect detection and control is carried on at Beltsville, Md., and Geneva, N. Y., in cooperation with the Agricultural Engineering Research Division and respective State Experiment Stations. Research on insect vectors of diseases is conducted at Beltsville, Md., and Sumner, Wash., in cooperation with the Crops Research Division and the Washington and Oregon Agricultural Experiment Stations.

The Federal scientific effort devoted to research in this area totals 6.2 professional man-years. Of this 0.6 man-year is devoted to basic biology and nutrition; 1.8 to insecticidal control; 1.1 to biological control; 0.6 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of equipment for insect detection and control; 0.6 to insect vectors of diseases; 0.7 to insect control treatments for commodities regulated by plant quarantine; and 0.5 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology and Nutrition

1. Insect Pests of Ornamentals. Mites resistant to insecticides had a thicker cuticle than normal mites in studies made at Beltsville, Md., with a Nitachi HU-11 electronic microscope. The electron micrographs of longitudinal and cross sections of the integument of the mites showed that the cuticle of a strain of organophosphate resistant two-spotted spider mite, Tetranychus telarius, is thicker than that of a nonresistant strain. The difference is apparently in the endocuticle component which was also thicker in the resistant forms (0.84 microns) than in the nonresistant forms (0.56 microns). The epicuticle and exocuticle of the 2 strains were of approximately the same thickness. Measurements of other components of the integument were also similar in the 2 mite strains.

In further tests with yellow water-pan aphid traps at Farmingdale, N. Y., twice as many aphids were caught in traps painted a deep yellow known as federal or safety yellow as were taken in traps painted a light or near lemon yellow color. Yellow sticky boards (6" x 12") set at intervals of 4, 8, and 16 feet trapped an average of 10.5, 9.3, and 8.2 aphids, respectively, per board.

Transient winged aphids, as evidenced by trap catches, were more abundant during July and early August than during April, May and June. Cucumber mosaic symptoms were present in many more gladiolus flowers in plantings made during June and July than in plantings made during late March, April and May. The late gladiolus plantings suffered the greater damage in confirmation of observations of commercial growers. There was a good correlation between movement of the winged aphids, the presence of young gladiolus plants, and subsequent development of cucumber mosaic. Gladiolus planted 1 to 7 feet from a source of the mosaic virus averaged 20% of the flowers developing symptoms. Plants grown 8 to 14 feet from a source of the virus averaged 12% of the flowers with symptoms.

2. Japanese Beetle. At Moorestown, N. J., a method for separating the sexes of the Japanese beetle in the pupal stage was developed. Male pupae have a three-lobed eruption on the ventral posterior segments formed during the development of the genital structures. This characteristic is not present on female pupae.

There is need for a practical procedure for rearing the Japanese beetle so that large numbers of all stages are available continuously throughout the year. At present research is restricted to those periods of the year when stages needed for studies occur naturally, and is confined largely to field-collected insects. In research to develop mass rearing techniques, most of the eggs introduced into steam-sterilized soil hatched but very few of the grubs developed. The development of third-instar grubs to the adult stage in both unsterilized and steam-sterilized soil was also disappointingly low, 25-30% and 9.5%, respectively.

B. Insecticidal Control

1. Insects of Ornamentals. Tortricid leaf rollers, including Platynota stultana, occurring on greenhouse roses in New Jersey, Pennsylvania and Maryland, were not controlled satisfactorily with DDT, parathion, or more recently, with carbaryl. Commercially prepared emulsifiable concentrates containing 24 ounces of Zectran with or without 8 ounces of Korlan per gallon applied at 1 quart per 100 gallons of spray gave complete control of the larvae in webbed leaves. A few larvae survived treatment at half this strength. Potato aphids were also killed when Korlan was added to Zectran. In tests with DDVP aerosols, adult moths and partly grown larvae of leaf rollers were killed but not full-grown larvae or pupae. Indications are that two or three well-timed applications of Zectran or DDVP will be required to bring an established infestation under control.

Studies at Sumner, Wash., have provided basic information on the biology, ecology and methods for controlling the lily bulb thrips. This pest feeds on 33 species of lily but on no other plants. Practical methods of control include immersion of the bulbs for 1 hour in water at a temperature of 110° F. The addition of 4 teaspoons of formalin per gallon prevented the spread of fungus diseases among bulbs. Information on the biology and control of other insect pests of lilies was brought up to date for early publication in the lily yearbook.

Studies in Oregon and Washington conducted by the laboratory at Sumner, Wash., confirmed previous indications that the western lily aphid, the melon aphid and the foxglove aphid may be controlled on Easter lily by applying phorate at 4 pounds per acre or Di-syston at 2 pounds per acre in the furrow when bulbs are planted in the fall. These systemic insecticides protected bulbs until harvesttime the following fall.

DDVP in aerosols with methyl bromide as the propellent, when applied at Beltsville, Md., to 35 kinds of greenhouse ornamentals including the most widely grown crops caused no plant injury when the temperature was 70° F. or below. However, at 80° the treatment caused injury to certain chrysanthemum varieties. This high temperature is required for maximum effectiveness of parathion and other insecticides having lower vapor pressures. Injury which sometimes followed treatments made at 80° F. in commercial greenhouses at first was thought to be caused by epichlorohydrin,

a rust inhibitor incorporated in most commercially prepared aerosols. However, aerosol tests in an experimental greenhouse with DDVP alone or with epichlorohydrin indicated that the high temperatures at which treatments were applied were responsible for the injury.

In performance tests with greenhouse temperatures of 50, 60, or 70° F., DDVP at dosages of 1 pound of 10% aerosol per 50,000 cubic feet killed resistant spider mites, leaf roller, cabbage looper, citrus mealybugs, thrips, aphids, and whiteflies at all temperatures. DDVP treatments made at low temperatures will avert the possibility of plant injury and be advantageous to growers of cool temperature crops in situations where it is inconvenient to raise temperatures in greenhouses to those required for effectiveness of other aerosols.

Strains of green peach aphids in commercial greenhouses in several eastern States have developed the habit of feeding and reproducing on young leaves in the growing points of shoots of carnation and chrysanthemum, and in the opening flowers. Lindane, parathion, malathion, TEPP, and sulfotepp have not given satisfactory control when applied in aerosols or sprays. Better results were obtained with DDVP but for this treatment to be successful two or more applications must be made at 3- and 5-day intervals. In preliminary soil drench tests with systemic insecticides in Maryland on carnation in greenhouse benches, dimethoate, Bidrin, and Meta-Systox-R at 8 lb. per acre gave complete kill of aphids on carnation shoots and flowers in from 4 to 7 days. In tests with a resistant strain of two-spotted spider mites on carnations, these three chemicals also gave the best control.

In tests on infested chrysanthemum, Bidrin and Meta-Systox-R at 8 and 16 pounds per acre as a soil drench failed to kill aphids in growing points or in carnation flowers in a commercial greenhouse in Pennsylvania. Further tests are needed to determine the reason for ineffectiveness of these materials under certain conditions. Organic matter in the soil or relatively poor translocation of the systemic insecticide in chrysanthemums may be responsible.

Poinsettias often require insecticidal applications after bracts begin to show color. In tests made at Farmingdale, N. Y., on greenhouse poinsettias in flower, injury was caused by malathion wettable powder and emulsion concentrate sprays, endosulfan wettable powder and emulsion sprays, and by dimethoate emulsion spray. DDVP and endosulfan smokes were not injurious. DDVP smoke may be useful for spider mite, mealybug, aphid, and whitefly control and endosulfan for aphid and whitefly control on poinsettias in addition to the commonly used sulfotepp smoke.

Among systemics tested against gladiolus thrips, dimethoate at 8 lb. per acre, when applied in the soil at the root zone of gladiolus at the 4-leaf stage of growth, gave complete protection of gladiolus flowers from attack by gladiolus thrips. Other systemics, at 8-lb. dosages, gave less than 60% clean flowers. Poor results with these systemics may have been due to

poor root absorption since most of the current season foliage and flower growth of the gladiolus is derived from storage tissue in the planted corm.

2. Japanese Beetle. Unceasing expansion of the area of infestation continually brings to light new problems concerning this insect and its control that require additional research. In screening tests of repellent materials for control of the adult beetle at Moorestown, N. J., extracts of Acacia moniliformis and Schinopsis lorentzi sprayed on foliage caused some reduction in feeding, but neither extract was sufficiently repellent to be of value in protecting favored foliage. Hercules 8717 and Hercules 9699 were equally as effective as DDT in killing beetles and in protecting foliage. Zectran was somewhat less effective than DDT or carbaryl. When exposed to sunlight, Zectran deposits lost practically all of their toxicity within 4 hours. DDT lost some toxicity during 8 hours of exposure. The toxicity of carbaryl was not modified significantly during an 8-hour period. In another test the addition of a polyethylene to sprays of DDT, heptachlor, and lindane prolonged the toxicity of deposits of DDT and heptachlor for a few hours but had no effect on the longevity of lindane.

Carbaryl with or without a sticker afforded practically complete protection to peach foliage from injury by the Japanese beetle for 1 week after spraying when the rainfall was only 0.06 inch. During the second week when the accumulated rainfall reached 1.96 inches, residues of carbaryl lost about one-half of their protective value, but those resulting from application of carbaryl plus Rhoplex Resin B-15 and UCAR Resin WC-130, emulsifiable boiled linseed oil, emulsifiable blown linseed oil, and emulsifiable tung oil lost about one-fifth of their protective value during the second week. At the end of the third week, when accumulated precipitation reached 3.12 inches, an application of carbaryl alone gave little protection to the foliage, but when this material was applied with stickers from one-fifth to one-half of the protective value of carbaryl remained.

The compound 2-phenoxyethanol did not act as a detoxicant for DDT. Beetles that had fed for 24 hours on leaves sprayed with 2-phenoxyethanol were equally as susceptible to DDT as those that had fed previously on unsprayed foliage. The addition of 2-phenoxyethanol to DDT spray did not inhibit the insecticidal action of DDT.

In laboratory tests with third-instar grubs in Sassafras sandy loam, at 80° F., Shell 8436 had about one-twelfth, Zectran about one-fifth, UC 8305 about three-fourths, and Telodrin about ten times the toxicity of dieldrin to Japanese beetle gruss. Telodrin was the most toxic of the chlorinated hydrocarbon insecticides tested against grubs, but its usefulness may be limited because of high mammalian toxicity. When a Zectran dust was applied and left on the surface of bare soil, only 35% remained after 3 weeks. When it was mixed with soil there was little loss during 3 weeks and 25% of it remained after 8 weeks.

The influence of the mode of application and ground cover on the persistence of the chlorinated hydrocarbon insecticides applied to soil at the rates recommended for control of the grubs was investigated. Residues from dust formulation treatments were about the same as those from granular treatments. When the insecticides were applied as top-dressings and left on the surface of bare ground, bioassays showed that 50% of the insecticides remained after aldrin and heptachlor had been exposed for 5 days, chlordane for 9 days, and DDT, dieldrin and toxaphene for about 28 days. Only 2% of aldrin, 6.5% of heptachlor, and 16% of chlordane remained after an exposure of 28 days. Volatilization appeared to be the major factor in reducing insecticidal residues on the surface of the soil. Incorporating insecticides with the upper 3 inches of soil immediately after application greatly reduced their loss to the atmosphere. Fifty percent of the insecticides remained after heptachlor had been in the soil for 7 months, aldrin for 11 months, chlordane for 17 months, dieldrin for 54 months, and DDT and toxaphene for more than 84 months. Grass cover reduced appreciably the loss of compounds applied as top-dressings to established turf, probably due to diminished air movement close to the surface of the soil and lower temperatures compared with those characteristic of bare ground. Fifty percent of the insecticides remained in light turf 2 months after applications of aldrin, chlordane, and heptachlor; 80% of the dieldrin and 90% of the toxaphene remained at the end of the 2-month period. DDT was not tested in light turf. In moderate and heavy turf 50% of the insecticides remained 6 months after applications of aldrin, chlordane, and heptachlor, 22 months after a dieldrin treatment, 35 months after a toxaphene treatment, and 56 months after a DDT treatment.

Lack of precise chemical methods for determining small amounts of mixtures of chlorinated hydrocarbon insecticides in nursery soils prompted research to develop suitable bioassay techniques. A practical method of assay for these insecticides in soils that can be used at any time of the year has been developed with drosophila as the test insect. On the basis of this research the Plant Pest Control Division authorized in 1962 use of the drosophila bioassay procedure to determine effectiveness of treatments applied to nursery soils subject to the restrictions of the Japanese beetle quarantine. When the mortality of the flies exposed to a soil under standardized testing conditions was less than 50%, the toxicity of residues in the soil was not adequate to eliminate grubs. When the mortality of the flies was between 50% and 90%, the toxicity was sufficient to eliminate the next annual brood of grubs. When more than 90% of the flies were killed, the toxicity in the soil was sufficient to eliminate at least the next two annual broods of grubs.

Since the amounts of chlordane, DDT and dieldrin needed in soil to eliminate newly hatched European chafer grubs are somewhat less than the amounts required to eliminate the Japanese beetle, the bioassay technique may also be used to regulate chafer quarantine soil treatments. The Plant Pest Control Division authorized in February 1962 use of drosophila bioassay to evaluate toxicity to European chafer grubs of soil containing residues of chlordane, DDT and dieldrin.

Laboratory stocks of drosophila may vary in the speed of their reaction to chlorinated hydrocarbon insecticides in soil. Because of this, sassafras sandy loam containing known amounts of insecticides has been used as a standard to determine and compensate for this variation. The restricted occurrence of sassafras soils on the Coastal Plain of the Middle Atlantic States areas suggested the need for a more generally useful standard. The geographical limitation on the bioassay procedure was eliminated by substituting a filter paper pulp tablet containing 2.4 µg. of dieldrin to regulate drosophila exposures of less than 10 hours, a pulp tablet containing 0.27 µg. of dieldrin to regulate exposures of approximately 24 hours, and a tablet containing 0.12 µg. of dieldrin to regulate exposures of approximately 48 hours duration.

When screening tests were conducted to evaluate the possible value of new insecticides against Japanese beetle grubs, the reaction of drosophila to the more promising materials was also determined. The flies appeared to be satisfactory for assaying the toxicity of residues of Zectran, UC 8305 and Shell 8436, but carbaryl was only slightly toxic to them. However, when piperonyl butoxide was added as a synergist to soil containing carbaryl, the mortality of the flies was proportional to the amount of carbaryl in the soil.

3. European chafer. In studies at Geneva, N. Y., to find new insecticides to control chafer grubs in soil, the phosphate insecticide GS-4072 had little toxicity. Variable results were obtained in tests with Telodrin but its toxicity ranged from four to eight times that of dieldrin.

In studies to determine the minimum amounts of insecticides needed to kill newly hatched grubs in Farmington loam, less than 5% of the grubs transformed to second instars in soil containing 0.25 pound of aldrin, 1 pound of endrin, 0.125 pound of heptachlor, 0.5 pound of lindane, 4 pounds of carbaryl or 0.5 pound of endosulfan per 3-inch acre. Third-instar grubs died before pupation when this soil contained 0.25 pound of aldrin or heptachlor, 0.5 pound of dieldrin, or 1 pound of chlordane per acre.

Temperature of the soil had a profound effect on the amount of chlordane and dieldrin needed in Farmington loam to kill 50% of the third-instar grubs during an exposure of 2 weeks. When the temperature was reduced from 80° to 70° F., the amounts of these insecticides had to be increased about four-fold to maintain the same rate of insecticidal action as that at 80°. A drop in the temperature from 80° to 60° required about a ten-fold increase in amounts used. In Berrien fine loam, about a six-fold increase in the concentration of dieldrin was necessary to maintain the same speed of insecticidal action at 70° as at 80° and a sixteen-fold increase was required at 60°.

The comparative amounts of aldrin, chlordane, dieldrin and heptachlor needed to kill 50% of the third-instar grubs of the European chafer or third-instar grubs of the Japanese beetle during an exposure of 2 weeks at 80° F. were 0.08 lb. aldrin for the beetle, 0.11 lb. for the chafer; 1.02 lb. of chlordane for the beetle, 0.82 lb. for the chafer; 0.26 lb. of dieldrin for the beetle, 0.20 lb. for the chafer; 0.10 lb. of heptachlor for the beetle and 0.13 lb. for the chafer. From the close agreement in the dosages required for these grubs, it appears that both species are equally susceptible to aldrin, chlordane, dieldrin and heptachlor.

The speed of insecticidal action of a granular formulation of dieldrin when freshly applied against third-instar chafer grubs in Berrien fine sandy loam at the rate of 2.5 pounds of the toxicant per acre was definitely slower than when the same amount was applied as a dust, but after being in moist soil for 4 months, the granular formulation killed grubs more rapidly than the dust.

C. Biological Control

1. Japanese Beetle. At Moorestown, N. J., a study to determine the relationship between the number of spores of Bacillus popilliae in the soil and the incidence of infection among third-instar grubs introduced into the soil, showed that practically all grubs surviving as long as 56 days in uninoculated soil pupated and only 6% became infected. A concentration of 50 million spores per kilogram of soil reduced pupation by 67%, one of 150 million spores by 87% and a concentration of 450 million or more spores per kilogram prevented pupation. One hundred percent infection among the grubs was obtained with 450 million spores per kilogram in 56 days at 82° - 85° F., with 1.35 billion spores in 52 days, and with 4.05 billion spores in 35 days. The results of this study indicate that applications of spores at the rate of 1.7 billion per square foot--equivalent to 450 million spores per kilogram in the upper inch of soil--should practically eliminate an annual brood of grubs before pupation, particularly if the spores are applied before eggs hatch.

The pathogen Bacillus popilliae was well established in asparagus and corn fields adjacent to a pasture in southern New Jersey where the milky disease had been colonized in 1936, 1.5 billion spores per kilogram being present in the soil in the upper 3 inches. Apparently the disease spread naturally into the cultivated fields. There were an estimated 7 million spores per kilogram of soil in the upper 6 inches of soil in the asparagus field and 30 million per kilogram in the corn field.

Cooperative experiments with the Plant Pest Control Division on the use of the milky disease bacteria in large-scale Japanese beetle control plots during 1959 and 1960, in which granular formulations containing spores were applied by airplane and ground equipment in Georgia, North Carolina and Ohio at rates of approximately 50 million and 100 million spores per square foot, resulted in establishment at all sites. However, by the end of 1962 the

pathogen had not built up as anticipated because of competing pathogens and chemical residues in the soil.

Intensive research on sporulation of the milky disease organism in order to to develop a medium for mass production is being carried on by the Northern Utilization Research Division.

A survey of 29 sites in 6 counties in southern New Jersey and in southeastern Pennsylvania where Tiphia vernalis had been released several years ago and at one time was known to be established revealed the presence of this parasite only at Valley Forge State Park in Chester County, Pennsylvania. At other sites the parasite could not be detected by visual scouting. Therefore, T. vernalis is now a minor factor in controlling the grubs in areas where once it was an important one.

2. European Chafer. At Geneva, N. Y., no parasites were found at nine sites in western New York where parasites of the European chafer from Europe--Dexilla rustica, D. vacua, Microphthalma europea, and Tiphia femorata--were released during the preceding 10-12 years. It is yet to be demonstrated that any of these introduced parasites have become established.

Assays were made in the fall of 1962 of soil from thirty-two 1-acre plots, where spores of Bacillus popilliae had been applied as spot treatments in the fall of 1954 within an area of 24 square miles in western New York, in a cooperative program with the Department of Entomology of Cornell University. Assays were also made of soil from areas adjacent to the plots. There has been a progressive decline in the density of populations of chafer grubs since the colonization of the pathogen. This could not be attributed to the pathogen, however, because only an occasional infected grub was found. There has been no significant change in the pattern of infection of the European chafer by milky disease since 1957. The incidence of infection among the grubs has remained low and at about the same level within inoculated plots and in the areas adjacent to them.

Assays were also made in the fall of 1962 of soils from small-scale plots where the pathogens Bacillus popilliae and B. lentimorbus were colonized in 1954 and in 1960. The chafer grub populations at the sites treated in 1954 have also remained low, but the assays show that the pathogens were spreading slowly in an irregular pattern from the original plots. Grub populations at the sites treated in 1960 have remained so low that there has been no opportunity for the pathogens to become established.

A study was made of the virulence of different strains of the pathogens Bacillus popilliae and B. lentimorbus to third-instar chafer grubs. A low level of infection was obtained with spores of B. popilliae produced in grubs of Cyclocephala sp., Phyllophaga anxia, and the Japanese beetle. However, when spores originally produced in P. anxia, P. fusca, or P. hirticula and then passed through chafer grubs, were again introduced

into chafer grubs, they were highly virulent. Spores of this pathogen obtained from naturally infected chafer grubs were also highly virulent to chafer grubs. The standard strain of B. lentimorbus would not infect chafer grubs, but a high level of infection was obtained with this strain after it had passed through a chafer grub, and also with the Maryland strain of the pathogen.

In cooperative studies with the Department of Food Science and Technology of the New York Agricultural Experiment Station at Geneva, the relationship between germination of spores of Bacillus popilliae produced on brain-heart infusion agar and the ability of the spores to produce infection in third-instar chafer grubs was investigated. When suspensions of 1,000 spores with ability to produce colonies on the medium ranging from 1.9 to 45.0% were injected into the grubs and incubated at 80° F., there was a trend for the incidence of infection among the grubs to increase progressively with germinative ability of the spores on the medium. After incubation for 4 weeks, the injection of 19 germinative spores produced infection among 53% of the grubs, and the injection of 450 of these spores produced infection among 85% of the grubs, confirming results obtained early in 1962.

D. Insect Sterility, Attractants, and Other New Approaches to Control

1. Ornamental Insects and Mites. Spider mites were successfully sterilized with apholate dips without causing damage to the host plants. Untreated females of the two-spotted spider mite (Tetranychus telarius) mated with males dipped in 0.0125% apholate in alcohol-water solutions, produced male progeny and dead eggs, but no female progeny. Females exposed to 2% apholate dip produced no viable eggs. Apholate-treated males were competitive with normal males in mating with virgin females. Adult females, fed on plant foliage previously dipped in 1% aqueous apholate, ceased egg laying after a few days and became sterile. Most adult males that fed for 24 hours on the treated plants were sterilized. Females similarly fed on residues and then mated with normal males, laid fewer eggs. These produced fewer male and fewer female progeny and numerous dead eggs. Some of the female progeny were sterile even though reared from eggs laid on untreated foliage. The sterilizing ability of apholate residues on foliage persisted for at least four days. Three parathion-resistant strains and one nonresistant strain of T. telarius and the nonresistant T. cinnabarinus varied only slightly in their susceptibility to apholate.

In studies of the effects of gamma radiation on the fertility of two-spotted spider mites and their progeny, untreated female mites mated to irradiated males produced fewer females as dosages were increased from 8 to 28 kr. Untreated females mated to males exposed to 32 kr produced only males and dead eggs. Females exposed to gamma radiation and mated to untreated males produced fewer females as the dosage was increased from 1 to 24 kr, and after exposure to 32 kr produced no females.

2. Japanese Beetle. Preliminary tests conducted at Moorestown, N. J., with apholate, tepa, and metepa as chemosterilants for the Japanese beetle, suggested that the topical application of 25 µg of either apholate or tepa will sterilize males. When the treated males were mated with virgin females, eggs that were produced did not develop. On the other hand, metepa used at the same dosage did not prevent completely the development of eggs.

3. European Chafer. In tests at Geneva, N. Y., the most effective chemically-baited trap for capturing chafers was one painted red and baited with a 3:1 mixture of Java citronella oil and eugenol. A more attractive lure is needed. In tests completed during the year, not one of 707 synthetic chemicals tested as lures was outstanding in its attractiveness to the chafer. Compound ENT-30,512 and N-butyl sorbate had about the same attractiveness as the Java citronella oil-eugenol bait. The results with N-butyl sorbate confirm those obtained with the compound previously. N-butyl sorbate, while definitely attractive to the European chafer, had little attraction to the Japanese beetle. In surveys for the chafer in Japanese beetle areas, the Plant Pest Control Division uses N-butyl sorbate since this lure catches fewer Japanese beetles. The chafer was not attracted to extracts of unmated male and female chafers.

A black light fluorescent lamp with a peak emission of 3650 angstroms was much more attractive to the chafer than lamps emitting shorter or longer wave lengths. In a 4-year study with black light traps in competition with each other, or operated independently, effectiveness increased progressively as the wattage of the lamps increased from 4 to 8, 15, 20 and 30 watts. About three-fourths of the chafers were captured by these traps from dusk to midnight; none were captured after dawn. When the effectiveness of a 6-watt black light trap was compared with that of a 15-watt black light trap, both operating independently on 12-volt batteries, the 6-watt trap caught three-fourths as many chafers as the 15-watt trap when chafer flight was heavy, and one-half as many when the flight was light. In spite of its lower efficiency, the 6-watt unit shows considerable promise for use in survey operations because it could be operated for 10 nights on a single charge in comparison with only 3 nights for the 15-watt unit. When populations of chafers were very low, black light traps captured some chafers even when none was seen in flight. During a 10-night period when one chafer was seen in flight on one evening and one on another evening, black light traps captured one or more chafers on 8 of the 10 nights.

E. Evaluation of Equipment for Insect Detection and Control

1. Japanese Beetle. In the survey program for the Japanese beetle, a 0.5-inch torch wick has been used for many years to dispense the anethole-eugenol attractant. A woven dental roll does not fray as readily as the torch wicking. In comparative evaporation tests at Moorestown, N. J., the same amount of attractant was dispensed by a

0.5-inch dental roll as by the 0.5-inch torch wick, indicating that the woven dental roll may be substituted for the torch wick.

2. European Chafer. In comparative tests at Geneva, N. Y., the same amount of N-butyl sorbate was dispensed by a 0.5-inch dental roll and by a 0.5-inch torch wick when both were exposed 1/8 inch above the cap of the bait bottle. Either type of dispenser may be used in the survey program for the chafer.

The attractiveness of black light to unwanted nocturnal insects presents a problem in practical usage of this trap to detect chafer infestation. In the more southern areas where populations of nocturnal insects are larger than in western New York, the 3/4-inch opening of the funnel in the standard trap became clogged by large insects. Placing a disk of 1/2-inch mesh hardware cloth in the funnel prevented clogging of the orifice and reduced the volume of extraneous insects in the receptacle by about 40% without modifying the numbers of chafers the trap captured.

F. Insect Vectors of Diseases

1. Insects of Ornamentals. The green peach aphid transmits amaryllis mosaic. Pronounced green and yellow mottle symptoms, large ringspots and chevron patterns in amaryllis leaves suspected for many years to be symptoms of a virus infection, have been duplicated in healthy seedling amaryllis with inoculations of sap and in transmission tests with the green peach aphid. In experiments, conducted over the past two years, in cooperation with the Crops Research Division in Maryland, the virus was transmitted mechanically and with aphids to tobacco, and other indicator plants in which it produced symptoms identifying it as a strain of cucumber mosaic virus. The problem has been difficult to solve because amaryllis develops new foliage quickly and normally at only one season of the year; and also because of the time required to grow healthy seedlings under isolation for inoculation tests and subsequent observations of symptom expression. Identification of the malady in amaryllis as a virus and determination of its mode of transmission has furnished a basis for making recommendations for control to commercial amaryllis growers and home owners in many parts of the country.

Sunn hemp, Crotolaris juncea, a plant being evaluated at Glen Dale, Md., as a new crop source for paper pulp, developed leaf mottle and severe stunting symptoms in 1961 and 1962 that later were proved to be caused by a strain of bean yellow mosaic virus. The green peach aphid was a highly efficient vector of this disease in greenhouse tests. From 50 to 100% of exposed plants became infected. Since the disease is a nonpersistent aphid-borne virus, any migrating aphid could be expected to transport the virus from outside sources or transmit it within the crop. Sunn hemp has a long season of susceptible vegetative growth and is severely stunted when infected with bean yellow mosaic virus. The successful culture of this crop will be limited to areas devoid of this virus in plant reservoirs or where few migrating aphid vectors occur during the growing season.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Japanese Beetle. There is a continuing need for improved treatments for nursery stock and farm products to eliminate infestations of the Japanese beetle to permit their movement without danger of spreading the pest. Research on the development and improvement of these treatments is conducted at Moorestown, N. J. When the treatments of balled and potted plants with ethylene dibromide formulation 440 or with ethylene dibromide-chlordane formulation 431 were revised in 1961, the application of these formulations was limited to those periods of the year when only grubs were present in the soil, largely because there had been little demand by the growers for treatments during the late spring and the summer. Since these treatments were effective in tests conducted during the year in eliminating not only the grubs, but the eggs, pupae, and adults in the soil, it was recommended to the Plant Pest Control Division that the seasonal limitation on these treatments be removed.

The possibility of treating samples of soil to destroy noxious insects before shipment to a laboratory for bioassay with drosophila as the test insect was explored. Fumigation with ethylene dibromide or methyl bromide was not satisfactory because residues of the fumigants, which were toxic to the flies, were not eliminated by aeration for 5 days. Heating the soil caused a loss of chlorinated hydrocarbon insecticides. Quick freezing where the temperature was reduced within a few hours to -15° F. had no effect on the insecticidal residues. The quick freezing procedure is a simple and practical method for eliminating all stages of the Japanese beetle and grubs of the European chafer.

Bioassay of soil from a commercial nursery where an insecticide-fertilizer mixture had been applied showed that the insecticide was well distributed through the soil by an initial cultivation followed by the usual cultural operations.

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